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Under the hood of
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Future





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26 GEAR OF THE YEAR

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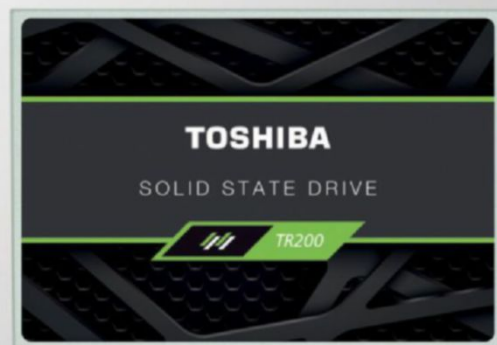
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Tuan
Nguyen

THE UNQUENCHABLE THIRST FOR HARDWARE

I AM A SELF-ADMITTED hardware addict. I love hardware. I obsess over hardware, and I'm always chasing the cutting edge. I'm also an early adopter, and that can be a problem at times. Some things just don't work the way they're supposed to when they're new. For the most part, I haven't had too many issues with being on the edge. There have been times when I've tried to convince myself to slow down. "There's no need to keep upgrading," I told myself. The self-hypnosis doesn't seem very effective.

What we've done this issue is put together a list of the very best gear of the year. Only products we think are badass make it on to this coveted list—the kind of gear you'll routinely find the staff here drooling over.

There have been countless times in my hardware life that I've lusted and drooled over hardware. The first time I got a CD-ROM drive was amazing. Optical technology, on an ultra-thin spinning disc? Want. A soundcard was an incredible piece of kit, too. For a long time, I had been hearing the musical horror that was the "PC speaker," so having something that played realistic sounds was pretty mind-blowing.

Two of my next all-time favorite pieces of gear were the 3dfx Voodoo card from Diamond, and then the Rendition Verite 1000. A company called Canopus made a custom 3dfx Voodoo 1 card that had 6MB of VRAM, instead of the standard 4MB of every other card. That Canopus card would definitely have made gear of the year if we were doing it back then.

Nostalgia aside, there are all sorts of goodies this year that you can get your

hands on. We obviously can't put all the best gear into one issue, so I'm going to sneak in a few myself. Here are some of my personal picks for best gear of 2017:

- **Devialet Phantom Gold speaker**—because I'm an audio nut.
- **AMD Ryzen Threadripper**—because challenging Intel is good for consumers.
- **HGST He12 12TB helium hard drive**—because you really can't ever have enough storage.
- **Dell S718QL Advanced 4K laser projector**—because lasers.
- **MrSpeakers Ether Flow**—the best headphones I ever had.
- **Vertagear Tricigger chair**—if you're going for a gaming chair, this is the one to get.

Lastly, I want to give a quick mention to Microsoft, for bringing back the much-loved Intellimouse, now called the Classic Intellimouse. This was the mouse that defined a generation, and continues to have an influence to this day. The original Intellimouse came out in 1996—that's 21 years ago—but it still feels great today, if you can get your hands on one. Thankfully, the new version is here now, complete with tastefully integrated white glow, and the same famous shape. I want one!

Tuan Nguyen is Maximum PC's editor-in-chief, also known as "the pointy end of the stick." He's been writing, marketing, and raising hell in the tech industry for 20 years.

submit your questions to: comments@maximumpc.com

THE NEWS

WPA2 Cracked with Krack

Huge hole found in Wi-Fi security standard

WI-FI PROTECTED Access 2 (WPA2), the encryption protocol used on the majority of Wi-Fi connections, has a major problem: Researchers from the University of Leuven in Belgium have published details on the so-called Key Reinstallation Attack—or Krack, for short—which breaks the encryption wide open. The problem is fundamental to the protocol, rather than any implementation of it, so everything using WPA2 is at risk, which is millions upon millions of devices.

WPA2 uses a nonce, an arbitrary number made for the process, during the initial handshake between devices, during which the encryption key is generated for all subsequent traffic. Frequent reconnections are anticipated with Wi-Fi, and the same nonce is used to quickly re-establish a connection. This is the weak point. An attacker can repeatedly send a handshake request and recover the data encrypted using the same key. This is bad news

for encryption, because you can work back through the data, and eventually untangle the keychain itself.

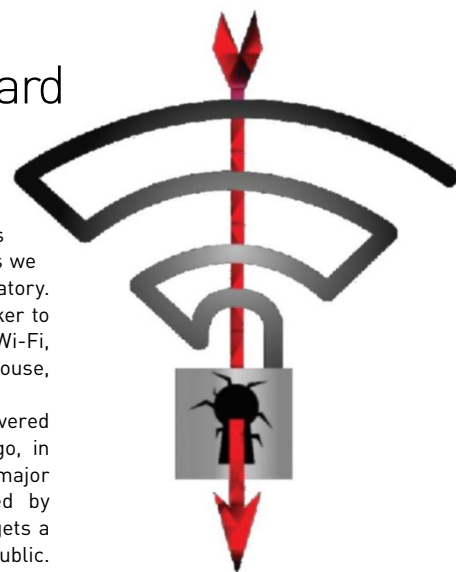
A successful attack would enable complete decryption of all data you send over a connection, passwords and all. It is also possible, depending on the device and network setup, to read data going the other way, too, maybe even add a little malware in the process. The researchers have made a successful proof of concept attack, which is impressive and scary to watch.

Secure websites are still secure; https provides another layer of encryption, so your banking details should be safe. Anything without a second layer is open, though, private emails and images included. At most risk is Linux and Android, which use a WPA2 client that can be fooled into using an all-zero encryption key. Windows and iOS are more secure, as they don't fully implement WPA2 (no real surprise there), however

nothing is immune. Before we all start to panic unduly, this is still only a concept as yet, and has not, as far as we know, escaped the laboratory. It also requires the attacker to be within range of your Wi-Fi, sitting in the same coffee house, for example.

The problem was discovered a while back—months ago, in fact. As with all such major security flaws uncovered by academics, the industry gets a heads-up before going public. It would be irresponsible to announce such a gaping hole in security without giving time for patches to be made available. If you've got Windows Automatic Update running as it should, you are patched as of October 10. If you are running Windows older than 7, you're out of luck. Microsoft's incentive to upgrade can be a little brusque at times. Apple took a little longer, but is now patched as well. Android is a thornier problem—there are so many versions and varieties out there, one patch will not cover them all. Google has pledged to fix it, so keep an eye out for updates. And no, changing your Wi-Fi password has no effect on this.

No security system is guaranteed secure, but heavyweight encryption has



The Krack vulnerability works because of an error of process at the root of WPA2, and affects everything using it—that's more than two billion devices.

a very good record. Witness the problem the FBI has with recovered encrypted cell phones, more than half of which it can't get into. It can lead to a sense of security, and complacency soon follows that. This security hole is not some buffer overflow in a particular piece of software, it is a fundamental flaw in the protocol itself, and potentially nasty. The Wi-Fi Alliance dropped the ball on this one. So, stay safe out there, and always install those recommended security patches. **—CL**



A successful attack would enable decryption of all data you send over a connection.



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PCIe DOUBLES ONCE AGAIN

Version 4 spec released, and 5 is announced

THE FINAL SPECIFICATIONS for version 4.0 of PCI Express have been released, and once more we're treated to a doubling of bandwidth. PCIe 4.0 runs at a base speed of 16GT/s. This translates to a little under 2GB/s per lane, so your x16 graphics card will get a healthy 31.51GB/s of bandwidth to play around with. As ever, it's fully backward compatible. This has been a long time in the making; it was first announced in 2011.

Faster is better, of course. NVMe cards and RAID systems will be happy, but most current hardware is comfortable with PCIe 3.0—it takes some serious gear to hit the buffers. Initially of more use is that you can halve the number of lanes for the same performance, saving those precious lanes for where you really need them. This is particularly important for processor PCIe controllers—these get full fast access to the CPU, and are in short supply. For example, many dual graphics card rigs have to share a x16 link, which is beginning to stretch the PCIe 3.0 specs.

Along with the healthy speed bump, we get a host of tweaks, lower latency, better scalability, RAS, and so forth. We also have OCuLink-2, a cable standard similar to Thunderbolt, which can take PCIe lanes where needed. Power is up, too. It's still 75W from the slot, but it allows for more than 225W extra direct from the PSU, although details are sketchy as yet. Before you get too excited, all this is some way off. We need PCIe 4.0 controllers in consumer processors first, and that is probably still years away. AMD has slated 2020, Intel hasn't committed yet, but is certainly keen to get Optane on to a faster bus.

It doesn't stop there, though—version 5.0 has been outlined as well, and this doubles things yet again. The PCI Special Interest Group is talking about 2019 for this. However, given how long version 4.0 took to cook, we can probably take that with a pinch of salt. **—CL**

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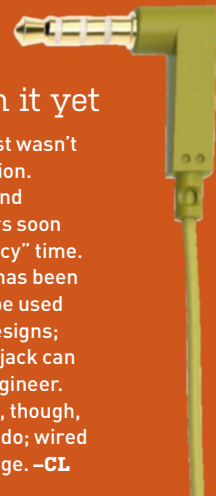
OFFICIAL DENIAL DOESN'T QUASH RUMOR



FACEBOOK HAS PUBLICLY denied that it is spying on us by secretly listening through our cell phone's microphone in order to better target advertisements. This follows months of rumors that this is exactly what it's doing. The rumor is born out of Facebook's almost uncannily accurate targeting. This was helped along by some seemingly convincing viral videos of people testing the theory out by talking about a previously untouched subject, only to see ads pop up for it later. Spooky stuff. Official denials on shady behavior from large corporations are never very convincing. The fact that they have to be made at all is worrying. However, it may be worth mentioning the frequency illusion at this point: The ads were there all the time, but you just didn't notice them until you looked for them. If you are seriously worried, pop along to your settings, and revoke Facebook's right to access your microphone. If that's not enough, it may be time for tinfoil. **—CL**

MICROSOFT TO SAVE THE HEADPHONE JACK?

New patent suggests there's life in it yet



WHEN APPLE DECIDED that the 3.5mm headphone jack just wasn't cool enough, and dropped it, there was some consternation. Apparently, even at that size, it took up too much room, and wasn't suitable for super-skinny hardware. Other makers soon followed, and it looked as though it was going to be "legacy" time. Now it appears the old dog may have a savior. Microsoft has been granted a patent on new forms of the socket, which can be used in devices thinner than the plug itself. There are three designs; all use a variation on an expanding socket, so part of the jack can project beyond the device. Simple and easy enough to engineer. Microsoft itself probably won't be making use of the idea, though, as it has killed off the Windows phone. Let's hope others do; wired headphones offer better sound, and don't run out of charge. **—CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

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TRAGEDIES

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Jarred Walton

TECH TALK

Intel's Coffee Lake Makes Six-Core Mainstream

COFFEE LAKE is both a significant upgrade to Intel's mainstream CPU line, and one of the longest delays between meaningful improvements. If you're an enthusiast who's already upgraded to a six-core, 12-thread (6C12T) processor, Coffee Lake might not seem like a big deal. We've had such chips since Gulftown on socket LGA1366 in 2010, though pricing was higher than many were willing to pay.

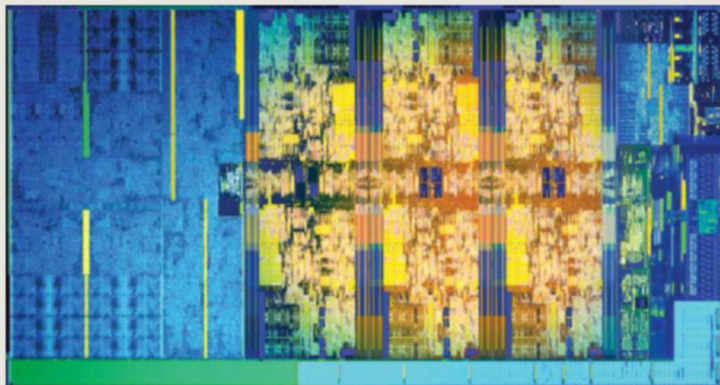
The i7-5820K dropped the entry price for six-core, 12-thread chips to \$389 in 2014—basically the same as today's i7-8700K. The problem is that Intel's mainstream platform, LGA115x, has stuck at four-core, eight-thread since 2009's first-gen Core i7s.

That's eight years of stagnation, largely because AMD never had a superior product. Ryzen changed that, and while it doesn't win every benchmark, the availability of competitive 8C16T chips at prices that undercut Intel's 4C8T CPUs looks bad, and the 6C12T Ryzen 5 parts cost less than most of Intel's 4C4T Core i5 parts. If you're running workloads that can benefit from more cores/threads, Ryzen has been an easy recommendation since launch.

After coasting on the mainstream platform for eight years, Intel has been able to rapidly release more cores and higher performance. Coffee Lake has better per-core performance than Ryzen, and clock speeds that are up to 30 percent higher. What's more, unlike the mesh topology used in Skylake-X, Coffee Lake sticks with Intel's ring bus.

The result is some killer performance, with the i7-8700K claiming top marks among 6C12T products. It's also the fastest CPU I've ever tested from a gaming perspective, with stock clock speeds as high as 4.7GHz—despite only having a dual-channel memory controller. Not to be outdone, the i5-8400 is a 6C6T part that includes reasonable (3.8–4.0GHz) clocks, and in a large suite of games, it matches the performance of a stock i7-7700K—at about half the price and two-thirds the power use.

The problem is that Coffee Lake uses the same LGA1151 socket as Skylake and Kaby Lake, except the pin-out has changed, and a new chipset and mobo is required. That's a low blow, even from Intel, considering Z270 boards aren't even a year



Coffee Lake still devotes a massive chunk of the processor die to graphics, which will largely go unused.

old. Coffee Lake is also the third new platform from Intel in 2017, which is insane. Add in AMD's various Ryzen and Threadripper launches, and 2017 is the most excitement we've seen in the CPU sector in ages.

If you upgraded to Kaby Lake, Ryzen, or Skylake-X, you don't need to upgrade to Coffee Lake—but the desire to do so may be hard to resist. I also have to ding Intel for sticking with its cheaper and less desirable thermal interface material, instead of solder. I overlocked the i7-8700K to 4.8GHz, but without delidding, it hit nearly 100 C under load. Ouch!

As exciting as 2017 has been, there are indications 2018 won't slow

down. Rumblings from AMD hint at architectural tweaks enabling better per-core performance and higher clock speeds, and Ryzen 2 (or whatever it's called) will run in existing AM4 motherboards. Not to be outdone, Intel could release an 8C16T Coffee Lake chip—though that would require a new die. And Intel's 10nm Cannon Lake chips should finally arrive by the end of 2018, possibly sooner. Here's to competition, and more reasons to think about building another PC.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.



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Alex Campbell

OPEN SOURCE

Linux PC Maker Raises \$1.6 Million to Build Phone

IT'S NOT EVERY DAY that a boutique Linux PC maker sets out to build a phone to compete with Android and iOS devices. It's even more rare to see such a project raise \$750,000 in a week. But if you're looking to face off with the top two most valued companies on the planet, you're going to need more than money.



Our world is ruled by cell phones. The numbers of mobile devices in the world swamp those of PCs. But with this many devices, one would hope to see more operating system choices.

One such choice is on the horizon: Purism's mobile Pure OS. Purism is a boutique PC maker that focuses on building privacy-respecting Linux PCs. The Librem 15, for example, allows for replacement of Wi-Fi card, storage, and RAM with minimal effort. Purism's Pure OS, like System76's Pop! OS, is a custom Linux flavor based on Debian. (Pop! OS is based on Ubuntu.) Like Pop! OS, desktop Pure OS is little more than a custom collection of stock apps, a desktop theme, plus drivers, and optimizations.

The Librem 15 features hardware kill switches for radios, and audio and video input (the mic and webcam). Purism's phone, the Librem 5, promises much of the same. While hardware kill switches are rare in the PC world, they're practically unheard of on mobile devices. Come to think of it, I see a lot of people with tape over the webcams of their PCs and MacBooks; I have never seen someone tape over their phone's front or rear cameras.

On the surface, Android looks like a champion of open source. The dominant OS is a tweaked and twisted Linux derivative, after all. But for those who

turn to Linux for privacy as well as security and stability, Android falls short. Taking Pure OS into the mobile space, Purism is offering privacy to users as well as flexibility. Pure OS will be a full-fledged Linux OS, and won't require the user to set up an account with Google or Apple. The Librem 5 will be capable of running any other Linux OS, as well.

Even with its privacy features, Pure OS has a tough battle ahead. The Ubuntu Phone never came to fruition for business reasons. (Canonical found it could make more money focusing on enterprise solutions.) Firefox OS didn't have enough airspeed to generate lift, let alone take-off. Even Microsoft failed to compete in the mobile space against Google and Apple.

Even developing bug-free Android flavors is tough. OnePlus had issues with the OnePlus 5 that prevented users from making emergency (9-1-1) calls.

If there's one thing that Purism has to lean on, it's the Linux community. At the time of writing, Purism had raised \$1.6 million in crowdfunding for the Librem 5 project, exceeding the \$1.5 million goal that would "guarantee" the project's completion. What's probably more impressive is that

A concept for the Librem 5, as seen in Purism's crowdfunding video.

Purism raised half of the goal—\$750,000—in just one week.

Purism has enlisted the help of the KDE and GNOME projects. Part of Purism's strategy is to lean heavily on upstream development, and to focus on getting that software to run on the hardware. That's a wise choice, especially as it won't be incumbent on Purism to create a new convergent desktop, like Canonical attempted with Unity. It also won't be up to Purism to fix Wayland's shortcomings by itself.

In the world of mobile, Android is king. Google's (mostly) open-source operating system has enjoyed wide global adoption, due to the relative openness of the platform and Google offering up the OS to hardware makers.

Do I like the idea of a privacy-minded phone that has a fully open-source OS? Of course I do. But given that the mobile battlefield is littered with the corpses of promising contenders, I'll have to keep a bit of skepticism for now.

Alex Campbell is a Linux geek who enjoys learning about computer security.



Pure OS will be a full-fledged Linux OS, and won't require the user to set up an account with Google or Apple.

THE LIST

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3

THIS WEEK IN TECH

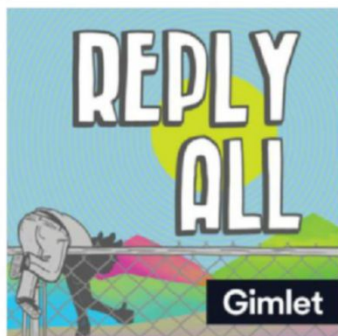
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6

REPLY ALL

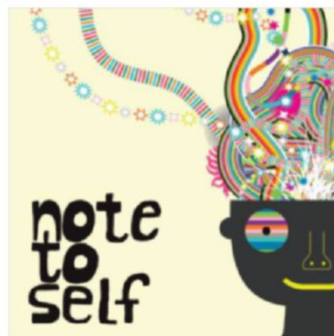
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HEAD TO

BY ALEX COX

Major Operating Systems

It's a subjective tussle as old as time (OK, not quite that old). What should you be running? What will make your computing life easy, and what will make it a living hell of crashes and bugs? We've pulled in the three big operating systems: Windows, macOS, and (presented in catch-all broad strokes) the entire Linux ecosystem. We have repeatedly banged our heads against all three over the past couple of decades, not just as desktop operating systems, but as servers, single-task machines, and so on. So, we've chosen to pitch them in battle over five categories that really make a difference. Let's fight!

ROUND 1

Hardware Compatibility

Windows' advantage as the largest operating system means the vast majority of devices offer 100 percent compatibility with it, generally straight out of the box, at least in recent times. Get something new, plug it in, and it'll work; if it doesn't, the latest drivers are just a few clicks away, and they're usually bang up to date with the latest patches and updates.

The same cannot be said for Linux—while the hard work of its community means a huge amount of hardware works just fine through open-source drivers, many of which are built in to the kernel, and thus available right away, it's rare for manufacturers to keep their drivers up to the same standard. The demand isn't high enough to justify the effort, particularly given that closed-source drivers tend to make the open-source community foam at the mouth and bang their fists.

The Mac's narrow hardware platform gives it a big advantage when it comes to peripheral compatibility, and most manufacturers are happy to support it, but beware: Cook yourself up a Hackintosh, and you'll find that forcing non-standard hardware to work with macOS is an arduous task.

Winner:
Windows

ROUND 2

Slickness

Apple's commitment to user experience is hugely evident in macOS, with all sorts of bells, whistles, and subtle niceties that make using it really rather pleasant. Aesthetically, it hasn't changed a huge amount since the introduction of OS X in March 2001, apart from flattening out a little, but it's had a bunch of navigational features tacked on—not all of which mesh together into a cohesive whole, it has to be said.

Windows is even more guilty of mixing up its styles. Recent iterations have seen a lot of simplification and forced friendliness crowbarred in, but plenty of old-school components remain, and this sometimes muddies the waters. Windows 10 is the slickest Microsoft OS yet, but its long legacy of minor changes means there's plenty of inconsistency on board.

And Linux? Well, Linux can be wonderfully slick. If you were to install the right desktop, and piece together the perfect selection of widgets, you could make it amazing—you really are spoiled for choice. But then you'll also need to put in the hours to make them work together without breaking, and whisper the secret magic word in exactly the right way.

Winner:
macOS

ROUND 3

Cost

Unless you're picking up a niche distribution packed with closed-source components for a very specific business-related purpose, with a support package tacked on to make sure someone else is on hand when you break it, Linux is absolutely free. You do not have to pay a single cent. Don't like the version of Linux you've downloaded? Then go grab another, and don't pay for that one either.

Credit, almost, to Microsoft as well: It made Windows 10 a free upgrade for a while (a semi-charitable way to push as many users on to its new operating system as possible), and seems to have dropped the concept of new paid-for upgrades altogether. Buy a Windows 10 Home license for \$119 and, if things stay as they are, you're set ad infinitum, at least until you need to install another copy on a new machine.

Apple hasn't ditched new versions, but it no longer charges for them. Indeed, it hasn't sold an operating system directly since OS X Snow Leopard, and that can be had for only 20 bucks if you need to refresh an old machine. The meat of macOS, and its subsequent updates, are paid for by the premium you have to pay for Mac hardware.

Winner:
Linux

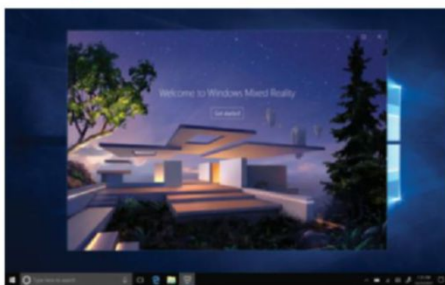
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macOS

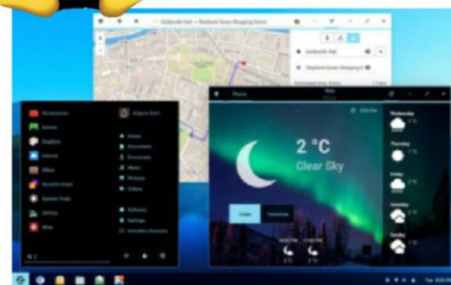
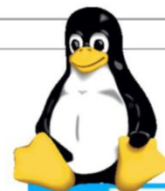


macOS: A collection of small iterations and Apple's customary clean lines.

Windows



Windows: Constantly evolving and the biggest operating system going.



Linux: Sometimes sexy (like Zorin, pictured), but always practical.

ROUND 4

Software

If you're a gamer, you want Windows—no question. Developers simply aren't inclined to pour resources into putting games on niche platforms—see Valve's not-entirely-successful Steam Machine project for proof. That's not to say there's not a large selection of games available for Linux or macOS, but you'll find a lot more for Windows.

Creative software has traditionally had a home within the stable, work-friendly environment of macOS, and it's certainly a great choice for hosting Adobe's Creative Cloud suite. However, running Windows doesn't preclude you from doing that, and—again—Windows' ubiquity is a huge factor in its software selection, with stacks more practical apps on offer.

Let's just not talk about the Windows Store, though: it's awful. Apple has fared much better with the App Store on macOS, but Linux scrapes it here. It's built around distribution networks, which pull the right software for your machine, and install it automatically. Yes, with a little cunning using WINE, you can convince just about any Windows app to run emulated on any platform, but we have to give this to Microsoft's OS in the end. Why work for it?

Winner:
Windows

ROUND 5

Versatility

There's a flavor of Linux for just about everything you can think of. From incredibly specific single-serving uses to desktops, servers, and enterprise machines, someone has probably already done the hard work of piecing together a custom distro. Even if they haven't, it's entirely possible to do it yourself, with distros such as Slackware and the Linux From Scratch project helping you start from nothing and build from there. Linux is also suited to a much wider range of hardware platforms. It can run on ARM devices, and you can find distros that run well on very old hardware.

Windows 10 comes in many (very similar) flavors, there's a little ARM support in the form of the free Windows IoT, and the Windows Server enterprise-level series exists, but that's the end of the line. Apple, meanwhile, doesn't even go that far: You can have macOS, or macOS with the Server upgrade, purchasable from the App Store. Of course, it only takes a little imagination to use Windows or macOS for whatever task you decide to set them to, but Linux's open-ended structure means it's what the operating system was meant to do from the start.

Winner:
Linux

And the Winner Is...

This clash was by no means a foregone conclusion, and objectively it's fair to say that no OS truly dominates. Perhaps the results don't match your own feelings or experiences. We won't argue. That's the thing about operating systems: They're subjective, and they're personal. They're the direct connection between you and your computing experience, and your own choice is going to be based on what matters to you most.

For us, Windows wins, primarily because being part of the largest crowd means you get the biggest software benefits, the widest range of support, and updates generally hit Windows first. Despite all this, it wasn't an easy win for Redmond's juggernaut OS, and that wide user base puts a malware-shaped sting in its tail.

As pleasing as macOS is to use, getting it on any non-Mac hardware means shattering a lengthy EULA, and potentially a lot of work toward hardware compatibility—but the same is not true in reverse. And as mature as Linux has become, and as ethically noble as it is, we still can't trust its stability as a daily desktop. 🔌

DOCTOR

THIS MONTH THE DOCTOR TACKLES...

- > High-End Gaming
- > Kaby Lake Boost
- > The Perfect Monitor

SLI Done Right

Dear Doctor, I finally joined the SLI club with a pair of EVGA GeForce GTX 1080 Ti FTW3 Elite Gaming 11GB GDDR5X cards. I also have a trio of Asus monitors that I hook up via DisplayPort.

What is the protocol for connecting my monitors and retaining SLI support? Each card has three DP outputs, totaling six DP connectors.

—Jerry Franco, Jr

THE DOCTOR RESPONDS:

According to Nvidia's Surround Configuration Tool, there are seven viable options for enabling SLI across as many as five displays. You need to use one DisplayPort connector on each card, then a third DisplayPort output on either the left or right card. This narrows the original seven possibilities down to three.

Just make sure your center (primary) display is connected to the left-most card, looking at their I/O brackets from the back of your PC.

Overclocking

Hi, Doc. I've been a reader of your magazine for some time, and I immediately head to "Ask the Doctor" each month. Being from England, some terminology is different, but



ASRock's Z170M Extreme4 motherboard should support memory speeds up to DDR4-3466, given the right modules.

the whole PC hardware scene is the same otherwise.

My question is simple, I hope. I have an Intel Core i7-7700K CPU, and I'm curious about overclocking. I've never modified a processor, but I'd like to get more performance out of this chip. The whole balance between higher voltages and non-standard bus speeds worries me, though. Is there an easy-to-use app that facilitates adjustments without the

danger of throwing too many volts at my CPU? —Ade Davis

THE DOCTOR RESPONDS: Just one generation ago, Intel's Core i7-7700K was the company's fastest quad-core CPU for LGA 1151-based mobos (now the Core i7-8700K gets that honor). A 4.2GHz base clock rate was unprecedented at the time, and Turbo Boost pushed the chip as high as 4.5GHz.

How much headroom is there left to exploit? An extra

500MHz, getting you to 5GHz, isn't unreasonable. You need a good thermal solution, though. Consider a closed-loop liquid cooler, such as Corsair's H110, or a big heatsink and fan, such as Noctua's NH-D15. You also need a Z170 or Z270-based mobo. The enthusiast-oriented chipsets make it possible to adjust the 7700K's multiplier, whereas Intel's mainstream platform controller hubs are not designed for overclocking.

Now, you mentioned being concerned about non-standard bus speeds. Fear not! The best reason to own a K-series CPU is its unlocked multiplier, so you can leave the BCLK at its default 100MHz. Overclocking is achieved by fiddling with the ratio limits. You can synchronize all the cores to make them operate at the same frequency, or create a curve that relaxes the clock rate under more taxing workloads. In the former scenario, a 50x multiplier pushes four cores to 5GHz. The latter might specify 50x when one core is active, 49x when two cores are used, and 48x for three and four cores.

Reaching those frequencies (and making them stable) requires more voltage. It's hard to say with certainty what's safe. Up to around 1.25V works for experimenting with a big

submit your questions to: doctor@maximumpc.com

heatsink/fan, while water cooling buys enough margin for a little more, say around 1.3V.

The Doc favors dialing in adjustments directly to his motherboard's UEFI, locking them in. But if you want a Windows-based utility, check out the Extreme Tuning Utility (XTU), available from Intel's website. Its "Basic Tuning" menu lets you toy around with core and cache ratios, while the "Advanced Tuning" page opens up more detailed performance and voltage options. Built-in benchmarking and hardware monitoring panes are useful for testing your overclock before committing it to the BIOS.

Super Screen

Hey Doc, I wonder if you could help me pick out a monitor. My HP ZR30w is 10 years old, and I just built a gaming PC with a Core i7-7700K on an Asus ROG Maximus IX Hero, a GeForce GTX 1080 Ti, 32GB of G.Skill DDR4 memory, a 512GB Samsung 960 Pro, 2TB Samsung 850 EVO, 6TB WD Black hard drive, and a Seasonic 1,000W PSU.

I want a new monitor, but there is not a single one that I would upgrade to. I know what I want: a 32-inch 3840x2160 IPS-based display, with HDR and 144Hz G-Sync. It doesn't exist, though. I don't want to switch between a 32-inch 4K panel at 60Hz for some games and a 27-inch 1440p one at 144Hz for others. This leaves me to choose between one or the other. Which would you pick? I don't really want an ultra-wide monitor because I still play a lot of older games.

How have manufacturers messed up on sizing and resolution? Pixel pitch should be taken into account. A 4K monitor should never be less than 32-inch, and 27-inch is perfect for a 2560x1440 screen. I read about the Asus ROG Swift PG27UQ, and was disappointed in its size and DPI. It should be 32-inch.

I apologize for the rant, but it's concerning when companies cannot make what gamers want. —Dave



The Intel Extreme Tuning Utility gives you access to overclocking knobs and dials from the Windows desktop.

THE DOCTOR RESPONDS: If you're unwilling to compromise on those specs, you'll be waiting a while longer. Asus's ROG Swift PG27UQ and Acer's Predator X27 come closest, as you know. But their AU Optonics AVHA-based panels are limited to 27-inch. And that size isn't trivial to manufacture. Recently, both Asus and Acer announced their respective models are delayed until early 2018.

While it sounds like you've done enough research to know what you want, don't write off smaller 4K screens. The Doc has a 28-inch Acer XB280HK and a 27-inch ViewSonic XG2700-4K in his lab for G-Sync/FreeSync testing, and despite their 60Hz refresh rates, games look great at 4K on both. If you're worried about tiny icons/text in Windows, display scaling was greatly improved in Win 10, worked on more for the Anniversary Update, and made even better in the Creators Update.

Even if there was a monitor with all of your requisites, a single GeForce GTX 1080 Ti averages 60–100fps in many modern titles at 3840x2160, with details cranked up. Given waning support for SLI as DirectX 12 becomes more popular, a second card would only help in some of your older titles you enjoy playing.

Choppy Playback

Dear Doc, I have a Sony FDR-AX53 4K video camera and recorded hours of content on

a trip to Hawaii (in XAVC-S mode at 3840x2160). I want to play it back on my Samsung UN65KS9000 UHD TV, but it's only smooth if I output from the camera to the TV via HDMI. If I copy files from my SDXC (Class 10/UHS-3) memory card to my HTPC (an Intel NUC), the content is choppy.

What is the best way to save and play back 4K (XAVC-S) content? Can I burn to a Blu-ray DVD and play from my 4K DVD player? Is a high-end NAS with Plex Media Server or Video Station on a Synology system the answer? I don't want to store all of my content on memory cards and use the camera for playback. —Nick

THE DOCTOR RESPONDS: 4K video playback is demanding. Have you tried monitoring resource utilization to gauge whether your host processor is struggling? Every generation of Intel's NUC boasts H.264 decode acceleration. Since the XAVC-S format is based on the H.264 codec, your playback software should be able to offload some of the task.

Lacking enough information to diagnose your issue more thoroughly, rule out over-taxed hardware first. Then, make sure your software supports what you're trying to do. There is no technical reason MP4-wrapped content shouldn't play back smoothly, and moving those files to a networked device simply adds another variable to troubleshoot.

Troubleshooting RAM

Hi Doctor, I'm having an issue getting the memory in my PCs running at its rated speed, rather than the motherboards' default. Both systems contain ASRock Z170M Extreme4 motherboards. One sports an Intel Core i3-6100, and the other is based on a Core i5-6600. Both sets of memory are from Corsair. The first is a 4x 4GB CMK16GX4M4B3000C15 kit, which is not on the supported memory list (though others in the family are). The second is a 2x 8GB CMU16GX4M2C3000C15 kit, which is on the supported memory list. Both motherboards are running the current BIOS (7.20).

The default memory speed is DDR4-2133, and both PCs are fine as long as I maintain that data rate. But if I try to use the XMP profile to get them going at DDR4-3000, I start getting random crashes and start-up errors. I've tried using different memory configurations, including swapping the sticks from one computer to the other, and using one stick on each board, but I get the same issues. I even RMA'd one motherboard, thinking that might be the problem (it wasn't).

Is there any way to set up the BIOS to make these motherboards stable at the memory's top speed? —Dan Z

THE DOCTOR RESPONDS: Crashes and errors sound like they could be related to insufficient voltage. Corsair states that its DDR4 modules include two XMP profiles. One operates at 1.2V and is officially supported; the second specifies 1.35V and is not. Make sure you're using the one with a higher voltage setting. If a kit is on ASRock's compatibility list, it should work.

Start by experimenting with the supported CMU16GX4M2C3000C15 modules and your Core i5. The other kit was designed for X99 platforms, and may have other parameters that affect compatibility with Z170. ⚡

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- Opt. Intel® Core™ i7-7820HK Processor
- 15.6" Full HD, 120Hz 5ms Matte Display (1920x1080) with NVIDIA® G-SYNC Technology
- Opt. 15.6" 4K QFHD or FHD IPS, Matte Display with G-SYNC
- NVIDIA® GeForce™ GTX 1070 8GB GPU
- 16GB DDR4-2400MHz Memory
- 250GB Samsung 850 EVO M.2 SSD + 1TB 5400RPM Hard Drive
- Full Color Programmable backlight Keyboard
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GEAR *of the* YEAR

2017 has been an incredible year for hardware. Here are our picks of the best hardware from the previous 12 months *BY THE MAX PC TEAM*

THE PC INDUSTRY rarely sits twiddling its thumbs, but 2017 was an incredible period by any standard. We've seen impressive new processor releases that we may not feel the full effect of for some years (competition is great for pushing things forward), cryptocurrencies reinventing graphics card pricing, more RGB LEDs than you could shake a cracked kyber crystal at, and a general focus on the whole PC ecosystem to make it more powerful and more customizable.

The timing of these advances is no accident, with the way we're using PCs continuing to develop in new directions, while reinvigorating older ones. The consoles that have diverted resources away from PCs for so long have had a faltering start with their next-generation platforms, so the PC has returned to the

fore as the number one gaming platform. But PCs are far more than just gaming systems, and even gamers are doing a lot more with their systems—streaming while gaming is commonplace, and that takes a lot of power. Throw in image and video editing, programing, website building, office work, rendering, and all manner of other pastimes, and all the power that the latest releases is unleashing is eagerly snapped up.

Over the next few pages, we highlight the gear that impressed us most over the last year. The hardware that stood above the crowd and not only showed what was possible now, but where the PC could go next. 2018 already looks like it's going to keep pushing things forward, though we doubt it will reach the heights of the last 12 months—but, hey, we can hope.



**KICK
ASS!**



CORSAIR ONE PRO

Corsair may be more synonymous with peripherals, but its first pre-built system absolutely delivers. Taking the company's knowledge of cooling, the One Pro uses a single large fan to draw air through the system in order to keep the high-end components cool, without making a racket while doing so—at idle, it trundles along at just 20dB. It also looks absolutely gorgeous, with its *Tron* vibe and satin finish making for a truly premium piece of gear. The performance is excellent for a single-card system, too, and for the money, you'd be hard pushed to do better yourself. Outstanding.

\$2,300, www.corsair.com



MSI AEGIS Ti3

The Optimus Prime looks aren't going to be to everyone's tastes, but the hardware you'll find throbbing away inside this tilted goliath could well have dissenters keeping their doubts in check. This is unquestionably a powerful machine: It packs a Core i7-7700K clocked at 4.2GHz, 64GB of RAM, 2x 512GB M.2 NVMe drives, and a pair of GeForce GTX 1080s in SLI. It tears apart our more serious benchmarks, but that's obviously not what it's built to do—it was designed to demolish games, and it does that with consummate ease. If you're looking for an unashamed gaming system, this is it.

\$4,300, www.msi.com



DIGITAL STORM VELOX

There are many ways that system builders can impress, but shipping a machine with one of the highest-clocked Kaby Lake Core i7s we've seen is a good starting point (4.9GHz, in case you were wondering). Toss in a pair of GTX 1080s in SLI, 32GB of RAM, and a 512GB Samsung 960 Pro, and you end up with a machine that eats most things you can think of throwing at it. It's a chunky machine for sure, although not as big as some of the systems we've looked at, but it's beautifully built, with a great eye for detail, and it's a performance monster as well.

\$4,737, www.digitalstorm.com

ORIGIN PC CHRONOS

We see plenty of powerful machines here at *Maximum PC*, and quite a few smaller ones, but few that manage to check both boxes. The Chronos is an exception to that rule, with its sub-console footprint hiding some incredible internal components: Along with the 10-core, 20-thread Core i7-6950X, you'll find a GeForce GTX 1080, 16GB of RAM, and a 6TB hard drive to complement the main 512GB Samsung 950 Pro M.2 drive. The Chronos performed brilliantly in our benchmark suite, and the general build quality really impressed us. Obviously, it's tightly packed inside, so upgrading isn't simple, but it is possible.

\$5,058, www.originpc.com





ORIGIN EON17-SLX

Laptops tend to fall into one of two camps—either thin and light or huge and powerful. The EON17-SLX falls squarely into the second grouping: This thing is a beast, both in terms of size and weight, and in terms of performance. It may be a laptop, but it boasts a desktop-beating spec. You'll find a desktop Core i7-7700K in here, not one of those lesser mobile models. That 17-inch 4K screen would be a challenge for any gaming system, so it makes sense for there to be a pair of GeForce GTX 1080 GPUs powering it. And power it they do—60fps is more than just a dream, even with the latest games at the highest settings.

\$4,787, www.originpc.com

ASUS ROG ZEPHYRUS GX501VI

A traditional gaming laptop is a big and bulky beast. Nvidia's Max-Q design changed that, by limiting the power draw and setting thermals for its GPUs, to make sure that it will fit in thinner machines. The Zephyrus was one of the first Max-Q systems we looked at, and it sure is an impressive ultra-slim gaming laptop. The resultant performance may be a shade off that offered by bigger laptops, but it's powerful enough to hit smooth frame rates in the latest games at the highest settings. So, a compromise, but one that still delivers, and doesn't sound like a jet engine when it's strutting its stuff.

\$2,699, www.asus.com





ULTRA-THIN
PRO

DELL XPS 15

The Dell XPS 15 is probably the closest thing the PC has got to a competitor to the Apple MacBook Pro, which may well be enough for some. It is actually an incredible machine in its own right, though, with its 4K Infinity Edge display featuring one of the smallest bezels anywhere, making for a great-looking machine. The core components are impressive, too, and while it's not quite a gaming specification, the mobile Nvidia GeForce GTX 1050 means you can get most things running on it with only a little tinkering (but not at the native 4K resolution). If gaming is a secondary requirement for a more serious machine, this is still our main recommendation.

\$2,499, www.dell.com



PREMIUM
GAMING

EUROCOM SKY X9E2

Asking a desktop to run a 4K panel at 60fps is a big ask, so it feels unfair to demand the same from a laptop, but that's exactly what Eurocom has managed to do with the Sky X9E2. This may have a frankly ludicrous price tag, but it rises to the challenge of extreme gaming, and delivers in spades. Dual GeForce GTX 1080s in SLI give it ridiculous gaming grunt, and as this is a non-Max-Q machine, it doesn't hold back. The rest of the specification is just as uncompromising, resulting in a system that really is the stuff of dreams, as long as you don't mind those dreams being hot and noisy.

\$5,683, www.eurocom.com

NZXT S340 ELITE

This has been a mainstay of our mid-range build since release, which goes some way to showing how reliable it is, and what great value it offers. We're big fans of its looks, with its tempered glass side panel, tight lines, and powder-coated finish making for

some great-looking systems. There are options to have a colored cable management bar and PSU cover, which also hold an SSD mount—though the black and white models look great, too. The fact that the top I/O connectors include an HDMI pass-through for VR connections is the icing on the cake. A lot of case for not much money. **\$100, www.nzxt.com**



BITFENIX SHOGUN

When you're looking at a high-end build, you want the case to stand out from the crowd, but also keep everything you have in it cool. The Shogun checks those boxes brilliantly, with its unique styling, support for varied cooling options, and enough neat touches to show off the components where it counts. The slanted tempered glass side

panels add a point of interest, while the RGB LED-lit SSD mounting panel means that your drives can be put on display while also hiding your PSU's cables. There's plenty of room to build in and house top-drawer components, as well as accommodate the radiators for your water-cooling antics. **\$140, www.bitfenix.com**



NZXT KRAKEN X62

It wasn't that long ago that most of us were happy to make do with a quality air cooler, but if you want to get the most from your CPU, it's hard to argue with the performance that can be unlocked with a good all-in-one. The NZXT Kraken X62 is the current pick of the lot, with subtle aesthetic improvements over the first generation, to produce a cooler that now looks as good as it operates. The infinity mirror on top of the water block supports some dazzling effects, and the cooler itself does a great job of keeping your temperatures lower than any other cooler we've seen this year.

\$156, www.nzxt.com

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INTEL CORE I9-7980XE

AMD may have revitalized high-end CPUs with Threadripper, but in a way, it only feels fair that Intel still carries away the performance crown. This is purely because its most expensive consumer chip also happens to be the most pimped-out piece of silicon to ever roll off its production lines. The Core i9-7980XE is an 18-core, 36-thread

chip that packs 24.75MB of smart cache. Its nominal operating frequency of 2.6GHz may seem pedestrian, but it rarely runs at that speed, usually being far closer to its Max Turbo of 4.2GHz. Yes, it's ridiculously expensive, but then at the same time, if you want (or need) the very best, this is it. **\$2,099**, www.intel.com



AMD RYZEN THREADRIPPER 1950X

So, while Intel's Core i9-7980XE takes the award for all-out performance, it should come as no surprise that AMD's top Threadripper scoops the prize for more sane high-end computing. At just less than half the cost of Intel's behemoth, but still packing a frankly ridiculous 16 cores and 32 threads, 32MB of L3 cache, support for 64 PCIe lanes, and running at 3.4GHz with a Max Turbo of 4GHz, on paper, at least, there isn't much difference between the two chips. In practice, Intel does have the lead, but if you're looking for a serious CPU to build a machine around that won't break the bank too much, then AMD is the way to go for us.

\$970, www.amd.com



AMD RYZEN 7 1800X

Expensive, multithreading monsters aside, what has 2017 given us in terms of more consumer-friendly desktop CPUs? Why, Ryzen, of course. To be honest, it's hard picking one chip that's definitely worth recommending over the rest, but the top-end package that is the Ryzen 7 1800X, with its eight physical cores, and ability to handle 16 threads, ultimately gets

the nod. It's an incredible number-crunching powerhouse that proves that AMD not only still has what it takes to produce a competitive chip, but that it can force Intel's hand to move things forward, too. The initial teething problems concerning memory compatibility have been sorted, and this is easily the most impressive technological advance of the last 12 months. **\$460**, www.amd.com



MSI X299 GAMING M7 ACK

The X299 chipset makes for a confusing platform, covering everything from the \$250 quad-core Core i5-7640X all the way up to the 18-core, 36-thread Core i9-7980XE. Ignore those confusing, and mostly irrelevant, lesser models, though, and you'll realize that the platform packs a serious performance and feature-

rich punch. This MSI mobo takes that notion to its logical conclusion, boasting a slew of features that you'll actually care about when building a high-end machine. It also looks the part, with its subdued color scheme. It's good for flexing your overclocking muscles as well, thanks to its intuitive BIOS and quality component choices. **\$380, www.msi.com**



ASUS CROSSHAIR VI HERO

The role of the motherboard continues to shift. Where once it was a vital cog in the performance machine, these days, there's little to separate a budget offering from the best money can buy. That's not to say that there aren't differences, but they're mostly with regard to features, aesthetics, or making it easier to overclock your chip of choice. The Crosshair VI Hero manages to impress on all these fronts, with an impressive feature list, great overclocking support, and all at a reasonable price. Anyone looking to pick up an AM4 motherboard to go with their new Ryzen processor could do a lot, lot worse.

\$255, www.asus.com



GIGABYTE Z270X-ULTRA GAMING

Such is the way of the world that one of the best motherboards to be released in the last year is for a processor family that hasn't had much to shout about. The Gigabyte Z270X-Ultra Gaming packs an incredible number of features into its wallet-pleasing price tag. Stock performance is strong, with plenty of scope for overclocking, if you're happy to familiarize yourself with

the BIOS. The design is surprisingly sober, too, as the more affordable gaming models tend to go down the dragons and damsels route all too often. We'll obviously be looking at more eighth-gen motherboards over the coming months, but this board does show that quality offerings can come a little late to the party and still impress. **\$155, www.gigabyte.com**

VIEWSONIC XG2703-GS

It's hard to recommend a single panel that is going to be perfect for everyone. It's what you're going to do with it that counts, and if you're into photography, then your needs are going to be very different from someone who just wants to make sure they don't miss a beat in their favorite shooter. That said, there's one panel that has stood out this last year, and that's ViewSonic's answer to the Asus ROG Swift PG279Q. This screen has a similar specification, including support for G-Sync up to 165Hz, but rolls in at \$100 cheaper. Perfect for gamers—and, in fact, anyone who cares about image quality.

\$699, www.viewsonic.com



GAMING IPS



PASCAL
GP102

NVIDIA GEFORCE GTX 1080 TI

It may have been a decent 12 months for graphics cards, but the fact that our only recommendation for a pixel-pusher comes in at \$700 shows that all is not well. Throw in a little cryptocurrency madness, and it's a year that many of us would sooner forget from a GPU perspective. Don't let that detract from the greatness of the GeForce GTX 1080 Ti, though, which is nothing short of stunning by any metric. With its 3,584 CUDA cores, 224 texture units, and 88 ROPs running at a maximum boost clock of 1,582MHz, this is a powerhouse of a graphics card that makes single-GPU 4K gaming a possibility. Expensive? Hell yeah—but, boy, does it deliver.

\$700, www.nvidia.com



PERFORMANCE
SSD

SAMSUNG 960 PRO M.2 2TB

While there are a lot of players in the SSD space, one company consistently manages to impress where others have faltered, and that's Samsung. The 960 Pro M.2 may have first seen the light of day just shy of a year ago, but it's still the drive by which others are judged. Impressive. The fact that it's available in capacities that

actually rival spinning platters is remarkable, especially when you consider that it's just 80mm long. Performance is key here, though, and the reason it has survived so well is because it still boasts the fastest consistent speeds around: 3,500MB/s reads and 2,100MB/s writes are not to be sniffed at. **\$1,266, www.samsung.com**

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HI-RES
AUDIO

ROCCAT KHAN PRO

It may be a tad confusing to discover that the first gaming headset to brandish the official high-resolution audio badge can be had for a relatively parsimonious \$100, but that's the thing about PC audio—it's never straightforward. So, despite offering up a stunning frequency response from 20Hz up to 40KHz, which delivers

without emphasizing the lows (as so many gaming headsets do), and being generally awesome-sounding, Roccat hasn't gone overboard with the overall design or materials used. You wouldn't know this was a premium piece of hi-res audio gear by looking at it, but your ears will quickly correct you to that fact.

\$100, www.roccat.org



 PRECISION
KEYBOARD


HYPERX ALLOY FPS

Focus on the fundamentals, and the rest is candy. That's clearly the ethos behind this keyboard. It looks stunning, thanks to its tight footprint, subtle lighting, and the

minimalist design, with its keys standing proud of the weighty steel base. You can get this keyboard with the usual gamut of key switches, but we've spent a lot of time

with the blue Cherry MX switches, and it's a glorious experience, although be warned: Your loved ones may not feel the same if they're in earshot. The integrated

USB port is for charging only, which is a bit of a missed opportunity, but otherwise this is a brilliant addition to any setup.

\$96, www.hyperxgaming.com



 CUSTOM
MOUSE

STEELSERIES RIVAL 700

It's impossible to talk about the Rival 700 without talking about balance: In terms of design, the company behind it, or its ethos, it's all about balance. It's also about choice. For instance, you get two cables in the box to choose from—one hard-wearing braided cable and a shorter soft PVC cable. You can also swap out the optical sensor if

you want, although you'd be hard pressed to find anything that competes with the PixArt 3360 that comes with it—it's quite simply one of the best we've ever had the pleasure of using, with a sensitivity ranging from 100–16,000dpi. The only downside is that it's a little pricey, but darn it's good.

\$86, www.steelseries.com

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GENERATION GAME

Give it up for Intel's 8th Gen Core processors, urges Jeremy Laird

INTEL'S 8TH GENERATION core processors have landed. They're the most exciting mainstream CPUs from Chipzilla in at least five years. But also the most confusing. In fact, Intel's 8th Generation Core isn't really a generation of CPUs at all. It's more a collection of products with common branding than a distinct generation of processors with something approaching a homogeneous feature set.

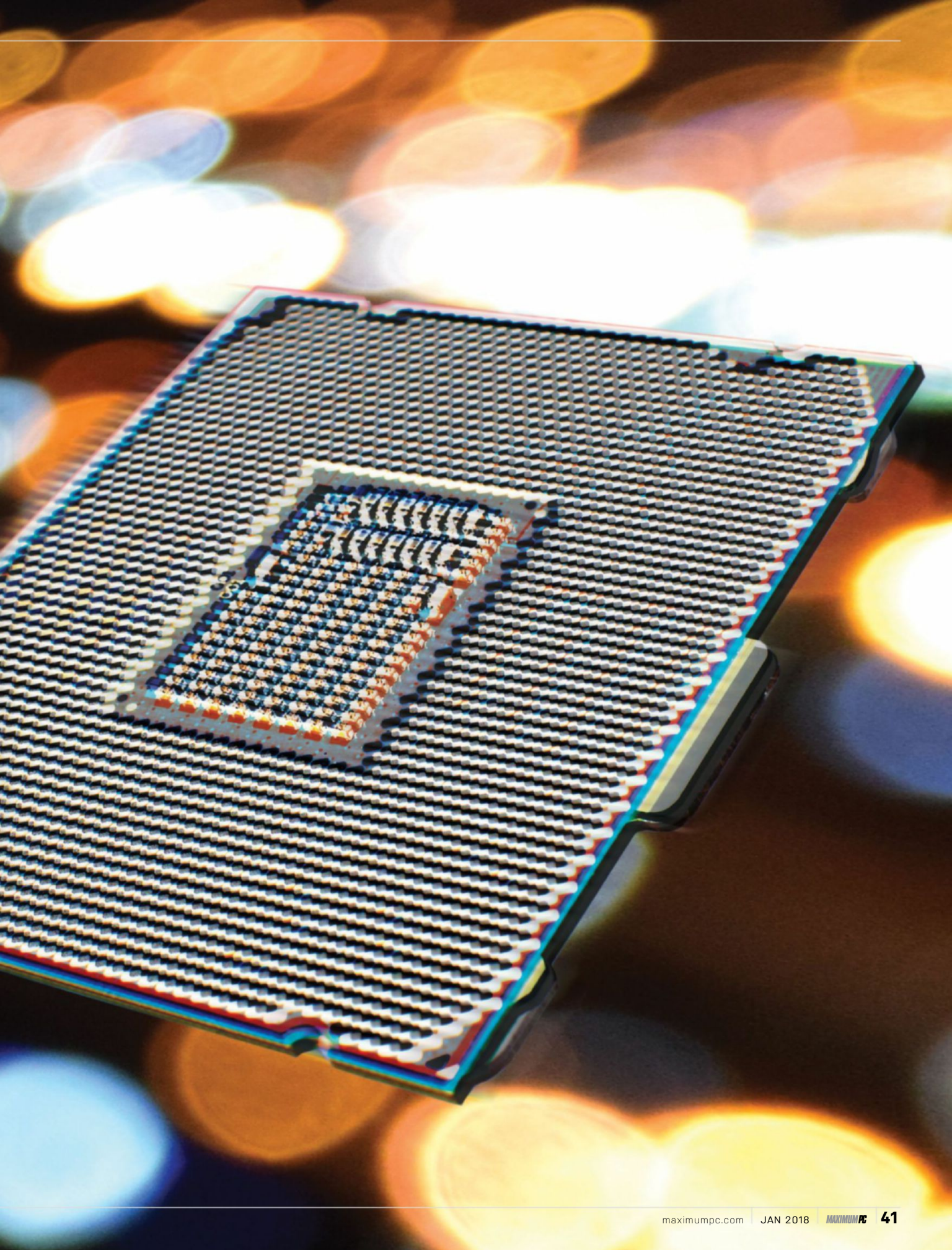
Eventually, 8th Gen Core will contain CPUs from three generations of processor design, and be manufactured on two silicon production nodes. But even with three generations and two production nodes, 8th Gen Core chips don't include Intel's new multi-core chips that range from 10 to 18 cores. Those fall under the 7th Gen banner. Intel never makes it easy to understand its product range.

If Intel's marketing can be utterly baffling at the best of times, 8th Gen Core remains really good news for the most part. For starters, we're looking at the first major step

forward in mainstream desktop CPU performance from Intel for a very long time. In simple terms, you're getting more cores at every mainstream price point. Hurrah! Mobile performance and battery life are on the up, too.

Where the confusion comes in is that, unlike previous generations, where being a part of a specific Generation of Core processor meant something in terms of features and capabilities, the simple fact of a CPU being 8th Gen doesn't tell you much. Instead, you're going to have to stay on your toes to keep up with the pros and cons of Intel's new range.

With that in mind, we've drawn together everything you need to know about these new CPUs. From poverty priced entry-level chips to mobile masterpieces and desktop killers that set new performance standards at certain price points, we've got the full low-down. So, now you'll know what to expect, where the best bang for buck is to be found, and which chips fit best with your PC usage. Let it rip!



CHRONOLOGICALLY SPEAKING, Intel's 8th Generation CPUs began where it so often does these days: with a mobile CPU announcement. But right off the bat, something wasn't quite right. A quartet of new "U" Series mobile processors debuted the 8th Generation nomenclature, including 8000 Series branding. But they were based on neither a new silicon production node nor a new processor architecture. Seriously?

That's worth repeating. Intel is calling the chips 8th Generation, but they are manufactured on 14nm production tech, which dates back to the Broadwell generation in 2014. Since then, Intel has revised its 14nm offerings with the Sky Lake and Kaby Lake architectures. So, this would

be the fourth new CPU family on the 14nm node, although Intel characterizes it as a revved-up "14nm+" process, with improved transistor fins, increased channel strain, and other tweaks that add up to a claimed 12 percent performance increase from process improvements alone.

That's unprecedented for Intel. Not long ago, Intel used to design CPUs to conform to its so-called Tick-Tock cadence of chip creation, in which the aim was to crank out a new architecture, then shrink it to a smaller production node in successive years. But in early 2016, Intel announced it was ditching Tick-Tock in favor of Process, Architecture, Optimization. In other words, in year one, Intel would shrink an existing CPU to a

smaller silicon production node. In year two, it would release a new architecture on that new node. And in year three, it would revise and optimize that new architecture.

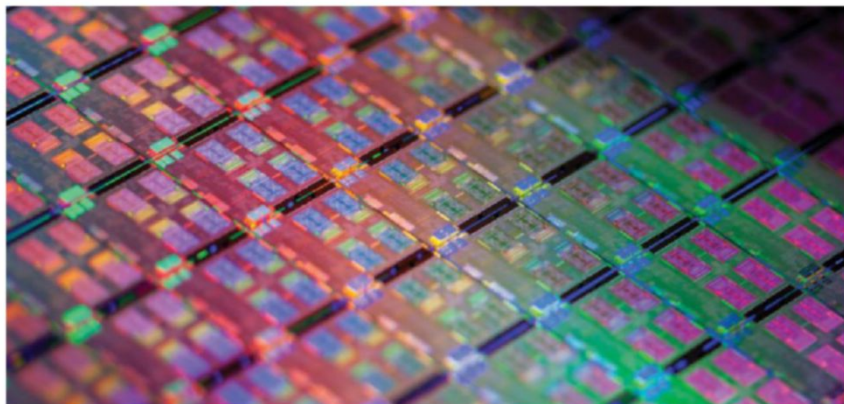
The move was an implied admission that Moore's Law is toast. Along with the rest of the integrated circuit industry, Intel is increasingly bumping up against the laws of physics. Shrinking its transistors every other year is no longer a goer. But that much we already knew before 8th Gen Core arrived. The surprising thing about those first mobile processors is that they don't even conform to Intel's new Process, Architecture, Optimization cadence. In fact, they're a mildly tweaked revision of the existing 14nm Kaby Lake architecture.

Arguably, of course, that's just details. What really matters is that with the new 8th Gen U Series mobile CPUs, Intel replaced a quartet of dual-core models with quad-core CPUs, and is doing so at slightly lower price points. The one downside involves clock speeds. Peak Turbo frequencies have been maintained or even improved, but base clocks have reduced a little. That reflects the fact that doubling the core count and maintaining both frequencies and power consumption, even with a tweaked 14nm+ process, is a non-starter.

As for specifics, at the bottom end of the relevant U Series range, Intel used to offer the Core i5-7260U for \$304. For that you got two cores and four threads clocked at 2.2GHz base and 3.4GHz Turbo. Now, Intel will sell you the Core i5-8250U with four cores and eight threads, a base clock of 1.6GHz, and a top Turbo speed of 3.4GHz. And it will set you back just \$297. Nice. At the other end of this U Series scale used to be the Core i7-7660U, a dual-core, quad-thread 2.5/4.0GHz model for \$415. Its replacement is the Core i7-8650U, a quad-core, eight-thread puppy rocking 1.9/4.2GHz frequencies, and yours for \$409.

If that's the good news on the mobile side, the bad is that it only adds to the incredible complexity and confusion of Intel's current product offerings. Right now, Intel lists no fewer than 144 individual mobile CPU models for sale from various generations of CPU. Just mobile CPUs, you'll note, and all based on the full Core architecture. Of those 144 models, all are either dual-core or quad-core. The upshot is that much of Intel's branding has become meaningless.

There are Core i5 mobile CPUs with two cores, for instance. There are Core i5 mobile CPUs with four cores. But some of them have Hyper-Threading and support for eight threads. Others do not. Meanwhile, customers are expected to decipher an impenetrable product suffix, with anything up to four numerals and two letters. Frankly, if you set Intel the task of creating



WHATEVER HAPPENED TO 10NM?

With Intel stringing its 14nm production node out to at least four generations (that's generations with a small "g") of Core processors, and having officially delayed the 10nm node, is Moore's Law dead? Moore's Law, of course, is the observation that computer chips double in complexity or halve in cost—or some mix of the two—every couple of years.

The simple answer is yes. If you define Moore's Law by that rigid two-year time frame, then it's probably done and dusted. Progress with conventional computer chips will continue, but at the slower pace we're already seeing. After all, Intel's first 14nm processors went on sale in late 2014. Nearly three years later, we've yet to see any 10nm chips, even if Intel

is promising them by the end of the year.

You could argue some new paradigm is needed, be that quantum computing or some other fundamentally new technology, if the next 40 years or so are to be anything like the last 40 years when it comes to the growth in computing performance. In the shorter term, however, the fact that Intel is no longer shrinking its transistors on a regular biannual cadence isn't the end of the world. Intel has shown with the 14nm process that significant gains can be had in terms of power consumption, courtesy of revising an existing process.

Of course, smaller circuit features aren't just about power consumption. They also allow more transistors to be made available, or the

same number of transistors at a lower cost. But even limited access to larger transistor counts might not be a total disaster.

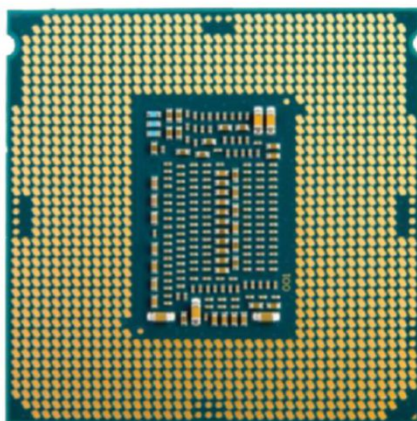
One effect of Moore's Law over the years has arguably been a certain inefficiency in chip design. Put simply, engineers have always been able to hurl more transistors at a given computational problem. But with Moore's Law coming to an end, chip designers will be much more incentivized to hone and polish their designs. Odds are, quite a bit of performance has been left on the table over the years. Clawing some of that back should buy several generations' worth of performance improvements while the industry searches for an alternative to the conventional silicon-based integrated circuit.

a product lineup expressly designed to beat customers into submission with the sheer, unfathomable complexity of it all, it could scarcely be any different from the array of similar mobile CPU models it does offer.

Despite all that, the new chips are still very welcome. They shift a whole class of notebooks instantly from dual to quad-core processing. Another 8th Gen novelty first seen with these U Series mobile chips is the debut of new branding for Intel's integrated graphics. Gone is the old "HD" moniker; in comes "UHD." The branding change reflects an increased emphasis on 4K or UHD resolutions. To achieve that, the new chips now natively support UHD resolutions via HDCP 2.2 content encryption and DisplayPort 1.2a connectivity. However, beyond those 2D video upgrades, the 3D graphics architecture is unchanged. That's significant. But hold that thought while we segue deftly to the desktop and the CPUs that arguably best define this new generation of chips. We give you Coffee Lake, the family of CPUs that we'd argue is the true 8th Generation Core architecture.

Once again, it's based on 14nm technology. And once again, Intel is claiming further revisions and advancements for its 14nm transistors. This time around, Intel is calling it 14nm++ and making some fairly bold claims. Overall, Intel says 14nm++ allows for around 24 percent higher drive current for 52 percent less power than its original 14nm process. What hasn't seemingly changed is much by way of architectural improvements. Intel isn't making big claims for things such as per-core performance. Nor has it added to the 16 native PCI Express lanes connecting the CPU to peripherals, such as graphics.

Instead, the really big news with Coffee Lake desktop chips is that they introduce the first increase in core count for mainstream Intel desktop processors since the Nehalem architecture of nearly a decade ago. Where once you got two cores, you now get four. And where you got four cores, you'll now be



It's the same CPU package, but you'll still need a new motherboard.

getting six. And you'll nearly, but not quite, get all that for the same money as before.

Intel has initially launched six CPUs, two each for Core i3, i5, and i7. The Core i3 models now offer four cores, while the Core i5 and Core i7 now pack six. If you're wondering how the latter are differentiated, it's via Hyper-Threading. Only the Core i7 models get that, so only the Core i7s are 12-thread chips. For the record, the Core i3s don't get Hyper-Threading. Nor, incidentally, do they have the Turbo frequency boost mode. You get the base clock, and that's it.

The exception to that is the unlocked "K" model in the Core i3 range, which is fully overclockable via the CPU multiplier. In fact, there's an unlocked model of all three versions. What's more, Intel has improved the overclockability of the K series models with more granular per-core overclocking. What it hasn't done, unfortunately, is ditch the cheapo thermal interface material (or thermal paste) that connects the CPU die to the processor lid. Soldering the lid to the die would be better for performance and overclocking, but also that little bit more expensive to manufacture.

Regards pricing, the two Core i3 chips and the entry-level Core i5 and Core i7



WHAT'S NEXT?

Intel's new 8th Gen family of CPUs is already pretty complicated, what with Kaby Lake refresh chips going into laptops, and the new Coffee Lake architecture for the desktop. But it's only going to get busier.

So far, all the new 8th Generation processors are manufactured using Intel's new 14nm++ silicon production process. It's basically a refined version of the 14nm process that first appeared in 2014 with the Broadwell architecture. However, next year will see the arrival of Intel's first 10nm processors, known as Cannon Lake. These, too, are expected to be marketed as 8th Generation CPUs.

Strictly speaking, Intel says it will be shipping the very first Cannon Lake CPUs by the end of 2017. But we doubt you'll be able to buy PCs or the bare CPUs until early 2018 at best. Either way, Cannon Lake is essentially a die-shrink to 10nm of the new Coffee Lake architecture. Our expectation is that it will likely be limited to mobile CPU models. For the next step on the desktop, you're talking Ice Lake.

Ice Lake is a CPU architecture that Intel has only recently confirmed to exist. It's a new architecture that will be manufactured with what by then will be Intel's revised 10nm+ transistors. Intel's says it's the successor to the 8th Generation Core family and thus will be the first official 9th Generation chip.

For now, that's pretty much all that's known about Ice Lake. Given that Intel's CPU core design has essentially flatlined of late, we're not expecting any major changes there. Instead, it's core count and the integrated graphics that offer the best opportunities for dramatic change. We'd like to see the core count increase again and, in an ideal world, see Intel ditch the pointless integrated graphics on Core i5 and i7 models in return for either lower prices or more cores.



The basic Core i3 now has four cores, Core i5 chips are now six-core beasts, while Core i7 models now have six cores and Hyper-Threading.



PICK A PLATFORM

With a new generation of Intel processors usually comes a new platform. Intel's 8th Gen Core chips are no different, even if it's too early to assume which members of the 8th Gen family the new motherboard chipset will align with.

For now, it's the six new desktop processors that are the first to be based on the Coffee Lake architecture. The new chipset they're getting is the Z370. Indeed, the Z370 is more a requirement than a gift. Officially, the new Coffee Lake CPUs will not run in older motherboards.

In some ways, that's frustrating. In most regards, the new Z370 is identical to the old Z270. It has the same broad connectivity, so we're talking up to 24 PCIe 3.0 lanes, six SATA 6Gb/s ports, with support for RAID 0/1/5/10, a total of 14 USB ports, with up to 10 in USB 3.0 spec (yup, still no native support for USB 3.1 Gen 2), and support for Intel's Optane memory as a boot drive. In fact, our understanding is that it's the same chipset, just under a new name.

The difference—or rather the reason, according to Intel, for requiring a new chipset and therefore preventing drop-in upgrades of older boards with the new Coffee Lake processors—comes down to power consumption. The new six-core models are said to guzzle more juice than the old 200 Series mobos can handle.

That's the theory. In practice, it seems as though it might just turn out that some high-spec Z270 motherboards could end up supporting Coffee Lake. According to Asus, some Z270 boards have sufficient power delivery to support Coffee Lake processors. All that would be needed are updates to the Management Engine and BIOS. However, this is something that Intel would have to enable. Motherboard makers would not be able to make that move unilaterally.



No new process node. No new architecture. But you do get more cores.

are all the same price as their 7th Gen progenitors, while the top Core i5 and i7 processors are a little more expensive. The other major change involves clock speeds. Peak Turbo speeds have gone up for the Core i5 and Core i7 chips, while base clocks are down across the board. But the base clock doesn't tell the whole story. For example, Intel rates the new six-core Core i5-8400 at 2.8GHz base clock. That sounds disappointing, even if it is only 200MHz below the 3GHz base clock of the earlier quad-core Core i5-7400. In practice, however, we found the 8400 runs at 3.8GHz under load across all six cores. That's just 200MHz off its top 4GHz Turbo speed.

That aligns with Intel's rating for the 8400 with all six cores loaded. You can refer to our table for the details, but thanks to the added cores, it's more important than ever to consider how fast each chip will run with all its cores under heavy load. That said, even the slowest of the new CPUs hits at least 3.6GHz with all cores loaded, while the top Core i7-8700K is rated at 4.3GHz with all six cores number crunching. In other words, Intel really is giving us the best of both worlds with these new processors. We're getting more cores, and clock speeds have only fallen off by a very small amount.

Less impressive, depending on how you look at it, are the integrated graphics

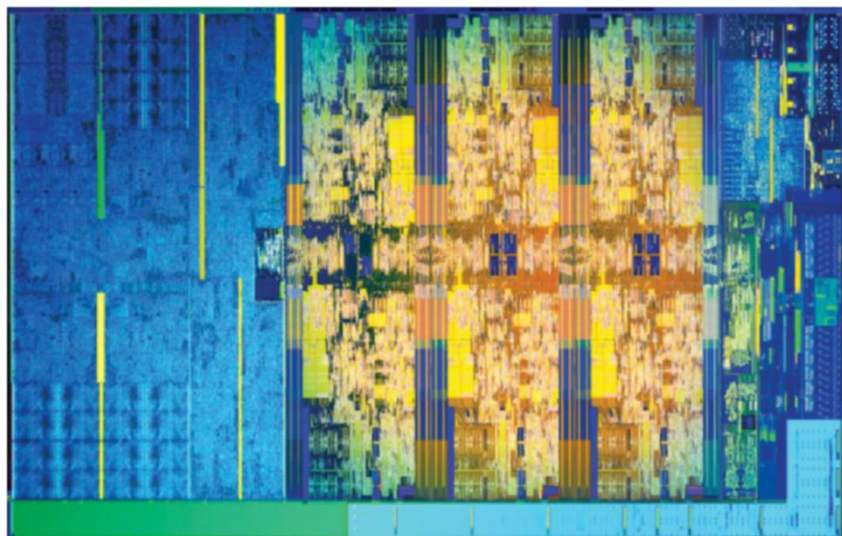
capabilities we alluded to earlier. Beyond the change in branding, there's little to report. Intel hasn't revised its 3D graphics architecture for Coffee Lake. The "new" UHD 630 graphics found in the new CPUs is the same in 3D rendering terms as the HD 630 in the 7th Generation Kaby Lake chips.

Is this an indication that Intel is finally giving up on integrated graphics for what you might call serious gaming? That's hard to say. What is for sure is that Intel's integrated graphics have never been any good for serious gaming, and even fall short for casual gaming with older games. There's a strong case for arguing these relatively high performance chips would be better off without the on-die graphics taking up any space at all. The Core i5 and i7 models, in particular, will almost certainly be paired with discrete graphics cards.

With that in mind, Intel could either make the six-core die smaller and cheaper by removing the graphics, then pass the cost savings on to consumers, or add more cores and create an arguably more logical and appealing CPU range, with four cores at the bottom on the i3 models, six cores for i5 chips, and eight cores for i7s. It wouldn't surprise us to see a hierarchy something like that in future generations.

While we're talking graphics, there's the question of gaming performance. For

"For now, the number of games that make good use of more than four CPU cores registers between slim and none."



Now with six cores, but also that pesky integrated graphics.

as long as we can remember, true multithreaded gaming has been just around the corner. It's a bit like cold fusion power, AI, or a cure for cancer. It's always just over the horizon, but never seems to get closer.

Admittedly, with the arrival of new graphics APIs in the form of DirectX 12 and Vulkan, you could argue that the long-promised multithreaded future for gaming is now tangibly closer. And that may be

true, but for now, the number of games that really make good use of more than four CPU cores registers somewhere between slim and none. With that in mind, what to make of the extra cores in Coffee Lake CPUs? For our money, it's good news however you slice it. If you're a many-cores denier, and you think four cores are plenty for gaming, the new chips get you a proper quad-core Intel desktop processor for just \$117. If, like us,

you think that six cores are a solid future-proofing bet, that's now a mainstream option from Intel.

Of course, while we're patting Intel on the back for finally delivering some more mainstream processor cores on the desktop, it's only fair to give its main—and, frankly, only—rival AMD the last word in all this. It's easy to imagine Intel's new-found largesse failing to materialize had it not been for the sudden uptick in competition provided by AMD's exciting new Ryzen processors.

With up to eight proper CPU cores in its own mainstream CPU socket, Ryzen packs a serious multithreaded punch. It's also much more competitive in terms of single-threaded throughput than AMD chips of late. So, while it's true to say that Intel almost certainly would have increased the core count of its CPUs of its own accord eventually, it's unlikely to be a coincidence that it's happening just when AMD upped its game. Indeed, the argument that Intel's moves of late have been a direct reaction to increased competition from AMD only looks more convincing when you consider the spectacular decision to increase the core count of its enthusiast-class desktop processors from 8 to 18 in a single generation. There's no way Intel would have done that without the AMD resurgence. ⚡

OLD AND NEW: SPECS AND PRICES

7TH GENERATION						8TH GENERATION			
Processor	Price	Cores	Base Clock	Turbo	TDP	Processor	Price	Cores	Base Clock
Intel Core i7-7700K	\$339	4/8	4.2GHz	4.5GHz	91W	Intel Core i7-8700K	\$359	6/12	3.7GHz
Intel Core i7-7700	\$303	4/8	3.6GHz	4.2GHz	65W	Intel Core i7-8700	\$303	6/12	3.2GHz
Intel Core i5-7600K	\$242	4/4	3.8GHz	4.2GHz	91W	Intel Core i5-8600K	\$257	6/6	3.6GHz
Intel Core i5-7400	\$182	4/4	3.0GHz	3.5GHz	65W	Intel Core i5-8400	\$182	6/6	2.8GHz
Intel Core i3-7350K	\$168	2/4	4.2GHz	N/A	60W	Intel Core i3-8350K	\$168	4/4	4.0GHz
Intel Core i3-7100	\$117	2/4	3.9GHz	N/A	51W	Intel Core i3-8100	\$117	4/4	3.6GHz

MAXIMUM TURBO SPEEDS BY CPU CORES UNDER LOAD

Processor	Cores/Threads	1	2	3	4	5	6
Intel Core i7-8700K	6/12	4.7GHz	4.6GHz	4.5GHz	4.4GHz	4.4GHz	4.3GHz
Intel Core i7-8700	6/12	4.6GHz	4.5GHz	4.4GHz	4.3GHz	4.3GHz	4.3GHz
Intel Core i5-8600K	6/6	4.3GHz	4.2GHz	4.2GHz	4.2GHz	4.1GHz	4.1GHz
Intel Core i5-8400	6/6	4.0GHz	3.9GHz	3.9GHz	3.9GHz	3.8GHz	3.8GHz
Intel Core i3-8350K	4/4	4.0GHz	4.0GHz	4.0GHz	4.0GHz	N/A	N/A
Intel Core i3-8100	4/4	3.6GHz	3.6GHz	3.6GHz	3.6GHz	N/A	N/A

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TECH PORN



1 ASUS WRT INTERFACE

When it comes to UI design, few can pull it off like Asus. Accessible via tablet, laptop, and more, Asus's WRT interface is an intuitive and easy way to configure and set up your AC5300, while also providing your own AiCloud, so you can access, stream, and share anything you want.

2 TRI-BAND SMART CONNECT

Thanks to its quad-core processor, the Rapture pre-emptively allocates wireless devices to channels depending on bandwidth demands, keeping more demanding networked systems on their own individual 5GHz bands, while the rest stay on the spare 5GHz and 2.4GHz channels.



Asus ROG Rapture Wireless-AC5300 Tri-Band Gaming Router

WHEN IT COMES TO NETWORKING, wireless is often synonymous with poor performance. Although it's commonly seen by the general public as "the future," you'll rarely find a device that can provide you with as much performance as that trusty old Cat 5 cable trailing between your router and your rig. In reality, Wi-Fi is quite the archaic technology.

So, with that in mind, why on earth would you invest in an aftermarket router like Asus's RT-AC5300? Because it alleviates all of these problems and more. Its quad-cored, 1GB RAM internal system powers a tri-band router design, packing two 5GHz wireless frequency

bands, and a single 2.4GHz one. Combine that with its extensive eight Gigabit LAN ports, one USB 3.0 port, one USB 2.0 port, support for link aggregation, and extensive multi-level AiProtection security, and it soon becomes apparent just how much of a beast this is.

All that aside, it's the design that's most striking. Featuring eight integrated antennas—four transmitting and four receiving—the AC5300's signal stability and range are exceptional. But is it worth the near-\$400 price tag? Well, if you have a smart device connected family, it just might make sense to invest in this space crab-style piece of gear. —**ZAK STOREY**



COMPUTER SUPERCOM



AND PUTER

Will we still have PCs in the future, and what forms might they take?

IAN EVENDEN INVESTIGATES

Twenty years ago, when PCs were universally beige, and *Maximum PC's* staff had a lot more hair, we probably would have nodded in agreement if someone had told us that the desktop's days were numbered. We'd used laptops, we'd heard about Moore's law, we knew things didn't get much better than Windows 95. It stood to reason that portable computers would take over, and that 17-inch CRT we could barely carry up the stairs would soon be on its way to the dump. That's partly

correct, as we thank any passing deity for flatscreens, but the desktop PC is still with us, and is really the only way to go if you want no-compromise computing power, be that for gaming, or 3D content creation, or 4K video editing.

Laptops are fine, and our phones and tablets have come a phenomenally long way, but there's always something that holds them back, be it insufficient cooling, limited RAM, the drawbacks of mobile

processors, or, in the case of touchscreen devices, an unintuitive user interface.

So the desktop endures, looking much the same as it did in the days of the 80286, only rotated 90 degrees into tower cases, and with more fans and lights, and a whopping great water block. Will it still be purring away on our desks in another 20 years, though?

One future route is already happening with the advent of cloud computing. Our PCs could become dumb terminals, akin to the thin clients of old, tapping into the huge processing and storage potential of data centers using high-speed wireless connections. They could all become touchscreen devices, small enough to tuck away in our pockets, then unfolding to gigantic size like some Tony Stark creation. They could be implanted into us, like something out of Iain M Banks's *Culture* novels or an episode of *Black Mirror*, connecting us to a central hub, and with a display like that of a smartphone constantly projected into our vision.

Or maybe they'll just stay the same, doubling in power every two years, and needing a new GPU even sooner. We went looking for answers.

UP CLOSE AND PERSONAL

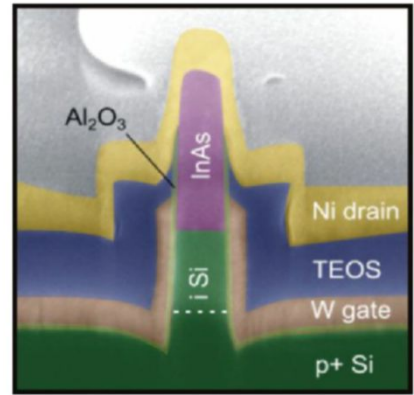
The term "PC" has evolved from meaning any type of personal computer to specifically those involving X86 processors and running Windows. Elsewhere, X86 + Unix = either Mac or Linux, ARM + Unix = iOS or Android, and ARM + Windows = discontinued. But those ARM chips are what's got Samsung poised to overtake Intel as the world's biggest processor manufacturer, and isn't the smartphone in your pocket as much of a personal computer as the one on your desk?

Many developments in future PC components are extensions of things

we're already familiar with: greater efficiency, using less power, and increased parallelism. A Ryzen 1800X may have eight cores, but a GTX 1080 Ti has 3,585. Yet while AMD's silicon is general-purpose, Nvidia's is specialized for graphics computations. Bringing this kind of parallel computing power to the mainstream, via something such as Nvidia's CUDA, Microsoft's DirectCompute, or other GPGPU programming languages, is a step in the direction of what's predicted for the immediate future of our PCs. Then there's 3D chips, such as those seen in Xpoint or the vertical stacks of AMD's HBM—these are about more efficient use of space, as well as, in the case of Xpoint, making use of a new approach to operating a memory chip. These technologies are here now, even if they're not widely available. Future technologies will take these innovations, and turn up the volume.

Looking ahead, by 2035 we should have cracked thermodynamically reversible computing—that is, logical operations that can be run backward from their result, because nothing is destroyed in their operation, and they don't increase entropy. This sounds a bit crazy—and is really only the tip of a whole iceberg of crazy—so we spoke to Professor Robin Hanson of George Mason University in Virginia, who is also a research associate at the Future of Humanity Institute of Oxford University in the UK, in an attempt to understand.

"When we run an engine, entropy is increasing," he says, prompting a trip to Google immediately. Entropy, it seems, is the amount of energy in a system that's wasted, unavailable to do work. The professor continues: "But if we want to reduce how much entropy increases, the slower we make the engine go, and the closer we can come to what's called a



A Tunnel FET can operate on about half the power of a traditional MOSFET transistor.

reversible process, where you could have made it go backward and got back to the original state. That's also true for computers: Almost all logic gate operations take two bits in and they send one bit out, therefore implicitly erasing one bit, and increasing entropy. Typically, we're erasing far more than one bit per gate operation, but that number has been declining over time."

This is where the year 2035 comes in—if you plot the number of bits erased by transistor operations on a graph, and continue the line into the future, it's a mere 18 years until it reaches one. "At that point," Prof Hanson continues, "we could keep reducing it, but we'll have to switch to reversible computing, where we have two bits in and two bits out, with nothing erased. Once we switch to reversible gates and reversible computers, then we can continue to reduce the amount of entropy per gate operation, but it will be because we run the gate more slowly. If you take the same gate, but take twice the time to do the gate operation, then it erases half as many bits. So when hardware gets cheaper, and energy gets cheaper, you will spend half of it on having more hardware, and half of it on running things more slowly."

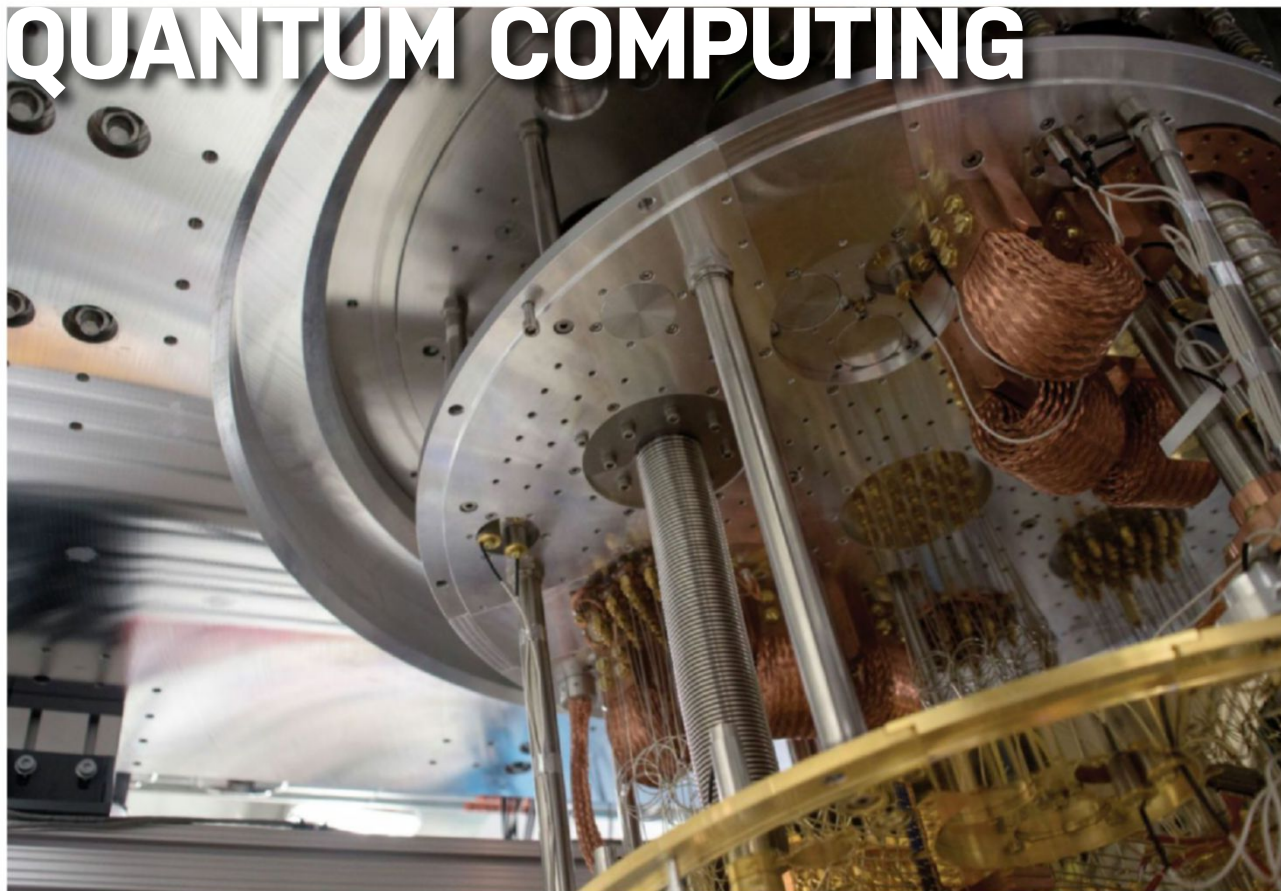
So what we are looking at are lots of slow, parallel processors, rather than the small groups of screamingly fast cores we see today. But that's not all: It will change the upgrade cycles, and what we budget for. "At that point, the rate at which technology improves, or hardware costs go down, is half as fast as it has been so far," says Prof Hanson. "Up until recently, energy hasn't really been the main cost—that's been the hardware itself. And so, every time the hardware is capable of running twice as fast, the computers are twice as fast. But with reversible computing, every time the hardware gets four times as fast, instead of running the computers four times faster, we will instead have twice as many of them running at half the speed. This

"The Tunnel FET looks like a MOSFET, and you can build a lot of the same circuitry with them."

DR KIRSTEN MOSELUND



QUANTUM COMPUTING



THE THEORY of quantum computing has been understood for a while now. Instead of using traditional transistor gates that can be in one of two states, 1 or 0, a quantum bit or "qubit" can be both at the same time, neither, or any combination. This hugely speeds up processing for certain calculations.

It comes at a cost, though: cooling. One method of building a quantum computer involves superconductors, and they need to be very cold—just above absolute zero. A water block isn't going to cut it. The cooling system is about the size of a hot water cylinder, even though the processor is less than an inch across. Then there's the "trapped ion" approach. This uses laser beams to trap and measure ions, which can be induced to carry out calculations thanks to quantum entanglement. This needs less cooling, but the machines can still be very large.

According to one researcher we spoke to on the subject, an interpretation of how quantum computing works is that it

makes use of computations across parallel universes. By doing this, it can solve certain problems in maybe just a few hours that even the fastest supercomputer in the world today would take billions of years to calculate.

Which sounds fantastic, but there are, inevitably, some problems. One is the sheer size, which we can expect to come down as the technology matures, and another is that, for the uses that you and your mom have for computers, there's simply no benefit in using a quantum model. The algorithm being processed needs to be specifically written to take advantage of the processor. So, while you'll probably never check Facebook, edit video, or play a game on a quantum computer, you may very well interact with an AI running on one. And the technically minded can use a five-qubit quantum computer today at <http://quantumexperience.ng.bluemix.net/qx/experience>.

means Moore's law will slow down by a factor of two."

Moore's law, which predicts a doubling of computing capacity over a period of two years, is already starting to break down in areas such as the speed of gate operations, but holds strong in the amount of energy used per operation. Many scientists are looking at ways to improve the rate of speed increase, and decrease the energy usage, through the use of new materials in chip design, and by changing the design of the

transistors themselves. IBM researchers in the US are attempting to press nanotechnology, such as carbon nanotubes, into service, while in Switzerland, Big Blue is testing out other naturally occurring elements, known as III-V materials.

BACK TO SCHOOL

Picture the periodic table thumbtacked to the wall of your chemistry class in high school. Silicon sits in the fourth column, with columns III and V to either side. Many

elements from both sides, when made into compounds, form very stable chemical bonds, and are semiconductors, like silicon, which means that although, in their natural state, they don't allow electricity to flow through them, they can be "doped" with another element to allow it, and this can be done in a controllable way. A lot of this is still exploratory science, but you may already own a piece of technology based on this idea—the laser diodes inside Blu-ray drives are made from gallium nitride—and

ELECTRONIC BLOOD



ANOTHER PROJECT coming out of IBM's Zurich labs will be of interest to anyone who's ever filled up a water-cooling reservoir and worried about spillage. Electronic blood is a fluid that circulates through the microchips themselves, drawing away heat, while at the same time providing power. In another example of hardware/wetware convergence, this is much the same way our brains work.

Using it means a change in the design of chips, so they contain microchannels that the "blood" can pass through to achieve laminar flow—an orderly, low-speed movement of the liquid in parallel layers, without any eddies or turbulence forming. It could change the underside of a chip, too—more of the 1,000-odd pins on the backside of a CPU are dedicated to power delivery than are for data flow. IBM is using 3D printing to produce its tiny cooling networks cheaply. Perhaps the

biggest change this could bring to PCs, however, would be in density. At the moment, we need large surface areas for contact with heat spreaders or active coolers. With the cooling fluid moving across inner surfaces, we could stack chips like a five-patty burger, and let the sauce—or maybe the cheese—take care of heat and power. This would cut down on the amount of good fresh air inside our PC cases, as well as using only a single pump, reducing noise levels in the process.

The fluid itself is made from chemicals with names like dihydroxyanthraquinone, and by acting as an electrolyte, and being charged as it passes electrodes, it's capable of supplying one watt of power, once pumping overheads are subtracted. This doesn't sound much in these days of 1,000W PSUs, but it's enough to power microprocessors, and the LEDs and lasers used in fiber-optic networks.

hopefully more should come to fruition before 2035.

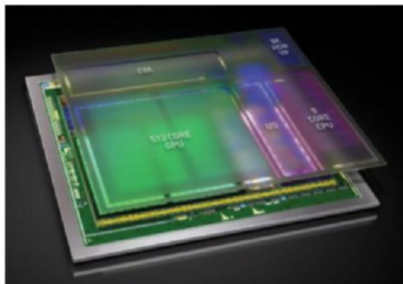
"The speed at which you can turn on a MOSFET is inherently limited," says Dr Kirsten Moselund from IBM Research. This is the breakdown in Moore's law mentioned above—the MOSFET, or metal oxide semiconductor field effect transistor, is the type of transistor most commonly used in a silicon chip, first patented back in 1925. "It doesn't matter what you make it out of, it's a physical limitation," she continues. "As we scale down our devices, we also want to scale down voltages, but it's very hard to scale down power beyond 60mV—you start to get into trouble. There are lots of people

looking into this, because it's beyond all the technical difficulties of scaling, it's something physical. And scaling down the voltages is probably the most important parameter for energy efficiency."

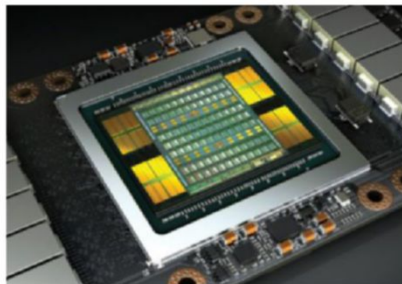
The search for a way around this has led Dr Moselund and her team to Tunnel FETs, a type of transistor that exploits the ability of electrons to tunnel through a barrier if that barrier is thin enough. This is quantum mechanics in action, making use of a strange property of electrons—that they can be either waves or particles.

"The Tunnel FET looks like a MOSFET, and you can build a lot of the same circuitry with them," says Dr Moselund. "But as it

operates on a different principle, in theory you don't have the same limitations." Indeed, a Tunnel FET can operate on only about half the power of a MOSFET—in simulations, at least. These transistors are made from, you guessed it, those III-V materials—indium arsenide and gallium antimonide are common choices. "III-Vs have a lot of really nice benefits," Moselund continues. "There are lots of them, and they have different properties, but what's generally good about them is many have very high electron mobilities [how quickly an electron, and therefore a current, can move through them], so you can trade speed for lower power, and many are optically active,



Nvidia's Xavier SOC uses 512 GPU and 8 CPU cores to be the brain of an autonomous car.



Also from Nvidia, the Tesla GPU introduces additional parallelism for AI use, and more.

so you can make lasers out of them, which you can't do with silicon."

Lasers are obviously great, but modern electronic devices have another problem—they leak. This is why they get hot and drain their batteries when you're not using them. The gates in the transistors don't shut completely, allowing small amounts of power to trickle through like a leaky faucet. Tunnel FETs and III-V materials have a greater ability to turn themselves off all the way, decreasing leakage and power loss.

The new materials don't completely replace existing ones; they're integrated into the silicon in a way that boosts its electron mobility, to increase performance at 7nm and smaller, meaning existing manufacturing processes can still be used. IBM, GlobalFoundries, and Samsung debuted a silicon wafer etched with a 5nm process earlier this year. The III-V materials are grown as crystals on a silicon substrate, then a process known as "epitaxy" deposits more material on top, forming structures such as nanowires and junctions, and even stacking them on top of one another. You can also mix up the recipe—what Moselund calls "tuning"—blending, say, 50 percent arsenic with 20 percent gallium and 30 percent indium, with a specific use in mind.

It's not just the structure of microchips that will change; the way computers are put together and treated is also in for a revolution. Professor Hanson believes that computers will one day be able to simulate and go far beyond the capabilities of the human brain. He calls these emulations "Ems," and his concept is not a little thought-provoking: When computing is advanced enough, it will out-compete humanity.

"A natural result is that humans will have to retire," says Hanson. "They're just not competitive. They could still work, they just can't earn much money that way. Collectively, humans get very rich very fast, that is, they own almost all the capital in this world, and if the economy doubles almost every month, human wealth doubles every month. For individual humans who don't own any wealth, that zero keeps doubling to zero, and those people are at risk of starving

unless they acquire some insurance, assets, or sharing arrangements. But collectively humans get very rich very fast.

EM POWER

"The Ems, however, they do not get rich," he says. "Their population quickly expands and wages stay at subsistence levels, but they are mostly OK with that—subsistence wages have been the usual case in human history. They're earning enough to pay the power bill, the cooling bill, the hardware rental, the communication line bill... which will presumably come in one big package."

This is treading rather closer to philosophy and economic theory than we're used to, so in an attempt to drag it back to more familiar terms of reference, we ask Hanson whether he thinks there's a future for the desktop PC. And he does. Kind of.

"A lot of people will continue to do office work at desks—it's kind of comfortable to sit in a chair," he says. "And they will want something around them to act as the interface to the computer they work with. Now, whether the computer is just sitting on the wall, or in their hands, or on the desk, that's much harder to say. They could have a box next to them or a server down the hall—it hardly matters from the point of view of them interacting with the computer. I like to use the same computer at home and in the office, so I prefer a laptop, but the incentive to use a laptop will get less the more reliable cloud services get."

Hanson goes on to imagine cities that glow red hot because they're occupied by the hardware and cooling needed to run Ems, with humans banished to more habitable parts of the globe, but the inference is clear—in the near term, PCs will continue to get more powerful, integrating new materials and structures into their designs. But as the cloud gets more important and reliable, and communication links get faster, a transition to something like today's supercomputer model could occur, with virtual computers held in the cloud, and eventually virtual workers there, too. It's safe for now, but the days of the desktop PC could ultimately be numbered. Sorry. ☹

A MATTER OF ETHICS

ONE ARGUMENT that can be drawn out of Hanson's work is whether these brain emulations would be conscious. After all, if the Ems do all the work, and humans retire and live on the profits, isn't there a word for that? As in *Star Wars*, where an army of apparently sentient droids obeys and are the property of the biological creatures, would we be condemning them to a nightmare of our own making?

The question of whether computers will be conscious may never be answered. Hanson asserts there's no way to tell: "If we mean it in the informal descriptive sense, of having some sense of self like humans do, that you can ask questions like 'what did you do yesterday?' or 'how did you feel about that?' then most computers are like that. And we could create computers that are more like that.

"If you mean there's something about a human that feels in addition to how it behaves, what it remembers, and its coherent story of itself, and these feelings are not reducible to plans, memories, or calculations, but are something else that's a part of us that's not included in the computery parts of ourselves, that there's some extra part of humans beyond the physical, we'll never really know about what causes it or where it comes from.

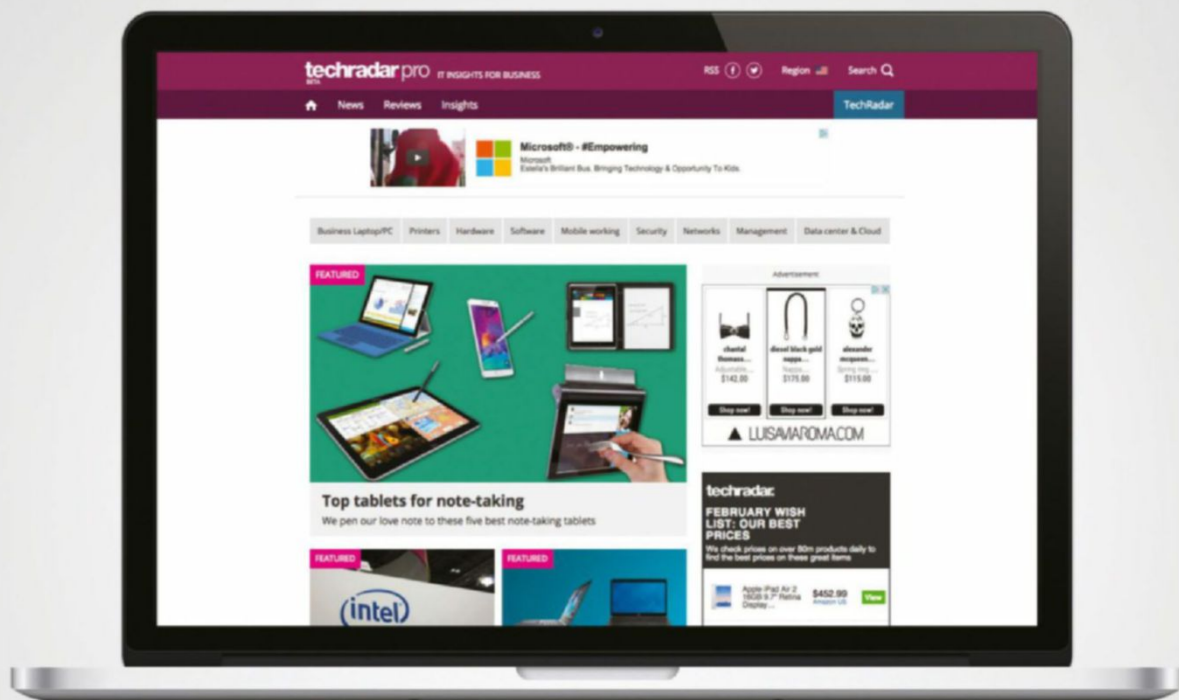
"You'll probably never really know if anybody you meet ever feels; the left side of your brain never knows whether the right side of your brain feels, and the you of today can never really know if the you of the past or the future really feels. All you know about these things comes through physical channels. And if people still think these questions make sense in the age of Ems, they will still disagree about it then."



Professor Robin Hanson of George Mason University in Virginia.

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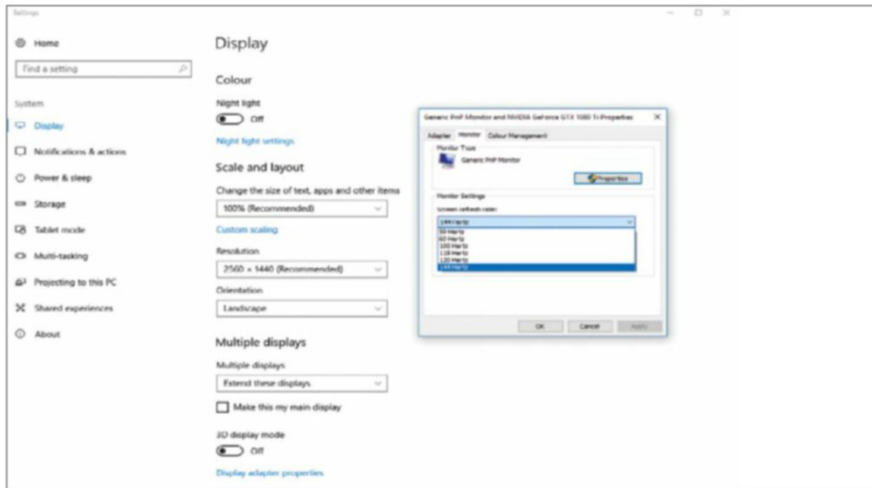
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HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

TIP OF THE MONTH



SETTING HIGH REFRESH RATES

120Hz refresh rate screens are beautiful to behold, so make sure you don't miss out on one of the best features available for display technology (if your screen supports it). Right-click your desktop, select "Display settings," then scroll down, and click the "Display adapter properties" link. Click the "Monitor" tab in the top of the new window. Go down to "Screen refresh rate," and select the refresh rate you want to use (higher is better). Hit "Apply," and the job's done.

MAKE – USE – CREATE



60
Create user-friendly rescue media with PE Builder



64
Get some WWII FPS action on your Pi with Wolfenstein 3D



70
How to build a mid-range AMD gaming machine



ZAK STOREY
DEPUTY EDITOR

GROWING UP

It's probably no surprise to learn that I'm the youngest *Maximum PC* team member. I recently dinged to level 26, and had quite the moment of realization when looking back at my two decades of system tinkering.

In my youth, I gamed a lot—some might say excessively—but as I've matured, I've found it more and more difficult to find AAA titles that hold my attention. Although it's still easy for me to drop into games and become more than proficient, my patience and free time is far more limited. I tend to find myself browsing the web, working, consuming media, and planning my next big adventure far more than investing in a new RPG or RTS.

Back in March, I fell in love with Samsung's CF791 super-wide screen. Its dramatic 21:9 aspect ratio, crisp pixel density, and 100Hz refresh persuaded me to take the plunge and purchase the \$750 screen, under the premise that it was perfect for gaming.

But I'm starting to wonder whether it was the right choice. Don't get me wrong, I still play games in my downtime, but high refresh rates, variable sync, and dramatic ratios aren't as important as my brain likes to think. The screen is perfect, but I'm not sure it's perfect for my circumstances. The answer? I think it's time I sold the Korean beauty to another PC enthusiast, and invested in a 40-inch-plus 4K behemoth instead. Combined with a re-evaluation and rebuild of my custom desk at home to something a little more professional (system and all), I might be on to a winner.

submit your How To project idea to: comments@maximumpc.com

AUTOPSY

WE DISSECT...



The volume/power button switches live on a single cable backed by a plastic frame.

About iFixit

iFixit is a global community of tinkerers dedicated to helping people fix things through free online repair manuals and teardowns. iFixit believes that everyone has the right to maintain and repair their own products. To learn more, visit www.ifixit.com.



Google Pixel 2 XL



The 8MP front-facing camera pops free readily.



BACKGROUND

Google revolutionizes the smartphone market with the Pixel 2 XL, offering new squeezability. We're hoping a teardown will reveal just how huggable it is. Follow along as we plumb the depths of Google's latest, greatest (and biggest) handset!

MAJOR TECH SPECS

- 6-inch plastic OLED (POLED) display with QHD+ 1440x2880 resolution (538ppi) and 3D Gorilla Glass 5
- Octa-core, 64-bit Qualcomm Snapdragon 835 processor (2.35GHz + 1.9GHz) with 4GB LPDDR4x RAM
- 12.2MP, f/1.8 main camera, with dual-pixel phase detection autofocus and laser detection autofocus; 8MP selfie camera
- 64GB or 128GB built-in storage
- Pixel Imprint back-mounted fingerprint sensor
- IP67 water and dust resistant
- Android 8.0 Oreo

KEY FINDINGS

- The Pixel 2 XL is a waterproof smartphone, which means all the ingress points must be sealed. We find our first evidence of Google's efforts in a gasket on the SIM tray. In a departure from standard smartphone opening procedure, we leave the iOpener behind. The Pixel 2 employs foam tape that can be separated without heat. Inside are long cables—a welcome respite from treacherous openings with past smartphones.
- We have to untether the display before going further. Its two cables are secured by plastic plugs in the midframe, and they only come out with some encouragement from a hefty pry tool. As in the original Pixel XL, a magnesium midframe separates the display from the innards, and provides a solid backing behind the display. Piggybacking on to that midframe, we find a brand new heat pipe. Looks like this phone might run a bit hotter than its previous incarnation.
- Last year, the HTC-built Pixel XL showed us a novel way to remove an adhered battery—a perforated outer label let you pull the battery out of its shell, then easily peel off the rest of the label. This year, it seems LG's industrial design doesn't include any provision for easy battery removal.
- We peel back some copper tape to unleash the XL's beast of a main camera. Although the megapixel count on this camera is close to last year's, the similarities between the sensors end there. This year, Google switched to a dual-pixel sensor, added optical image stabilization, and opened the aperture up to f/1.8 from last year's f/2.0.
- Along with a few other connectors, all that's holding the motherboard in place are the midframe screws. The 8MP front-facing camera pops free readily, and can rest easy, knowing it's a full megapixel better than the latest iPhone offerings. With the meat of the Pixel pulled out, we just have a few case peripherals to attend to.
- Repairability Score: 6 out of 10 (10 is the easiest to repair). Many components are modular and can be replaced once the display assembly is removed. All the screws are common Phillips #00 screws. The display is still thin and poorly supported, especially around the grilles, but foam adhesive makes the opening process easier. The battery's loss of pull-tab adhesive, plus tightly walled-in placement, makes it harder to remove. The stubborn midframe and tight-fitting display cable mean more labor-intensive repairs. 🔧

Create User-Friendly Rescue Media

YOU'LL NEED THIS

A BLANK DVD OR USB FLASH DRIVE

The USB flash drive needs to be at least 2GB in size.

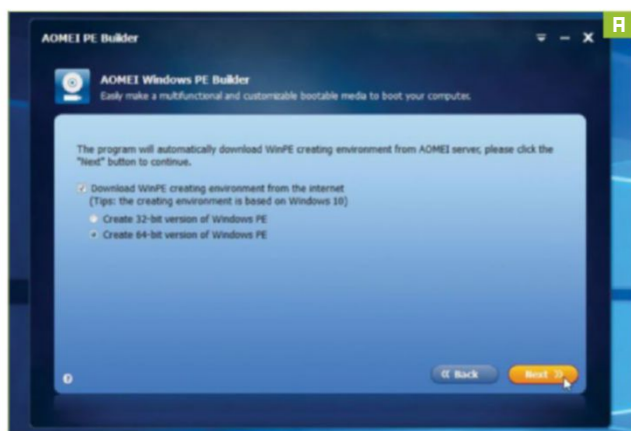
AOMEI PE BUILDER

Available for free from www.aomeitech.com.

IF WINDOWS FAILS TO BOOT, or you're otherwise locked out of your system, what can you do? Built-in recovery tools are certainly helpful, but they're not the most user-friendly. Microsoft developed a special "pre-installation environment," called Windows PE, which gives you access to a cut-down version of Windows that can be started from a bootable DVD or USB flash drive. It's basic, but it contains a familiar, user-friendly graphical interface that gives you access to your system even when it won't boot.

Creating this recovery media by hand can be tricky, but AOMEI PE Builder 2.0 doesn't just simplify this process, it makes it possible for you to build your own customized recovery disc, complete with the tools you know and trust for recovering data, restoring a previous backup, researching the problem online, and even performing certain repairs to bring your ailing PC back to life.

In this tutorial, we're going to show you how to build (and use) your own customized rescue media using PE Builder, which now runs on all flavors of Windows, from Windows XP up to the latest iteration of Windows 10. Without further ado—and while your PC is still working correctly—let's jump on the recovery wagon. —NICK PEERS



1 DOWNLOAD AND INSTALL

Head over to www.aomeitech.com/pe-builder.html, where you'll see a pair of links, for 146MB and 72MB downloads. The larger download contains AOMEI's Partition Assistant and Backupper utilities, which will be incorporated into your rescue disc. These are key tools—Partition Assistant can recover lost and deleted partitions, for example, while Backupper can be used to take a full system image of your drive—so we recommend downloading the 146MB version.

» Once downloaded, simply double-click PEBuilder.exe, and follow the on-screen prompts to install the software. Once complete, launch it from the Start menu or via a search for "AOMEI."

2 SELECT RESCUE DISC SYSTEM TYPE

The opening screen provides a series of hyperlinks, explaining various aspects of the rescue disc's interface, as well as included tools and utilities. Once you've reviewed these, click "Next." By default, "Download WinPE creating environment from the Internet" is selected—it's required if you're running Windows XP, Vista, or 10, and is recommended (but not compulsory) on Windows 7, 8, and 8.1, too [Image A].

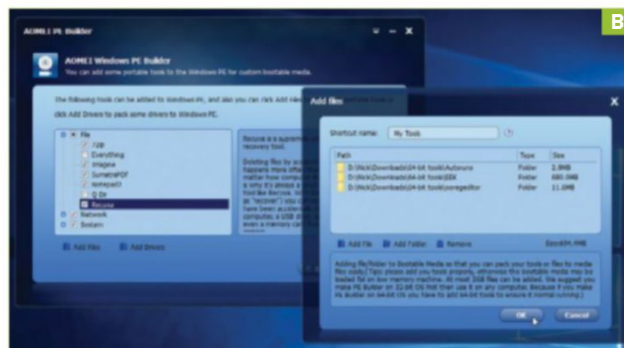
» Your key choice here is 32-bit or 64-bit. Typically, you should choose the same system type as your own Windows installation

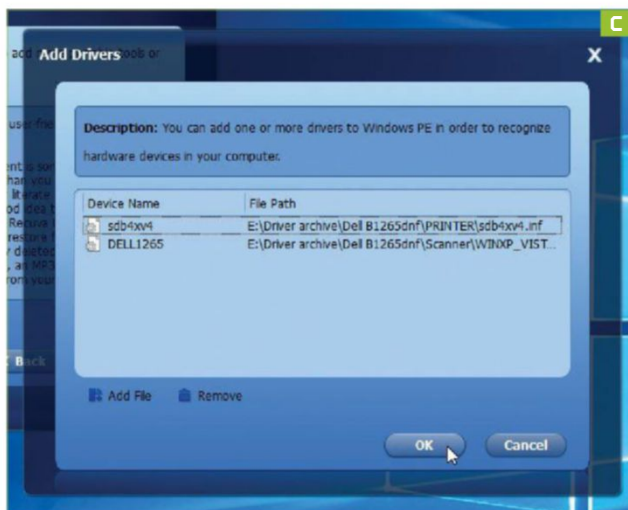
(press Win-Pause/Break if you don't know this), but there are two considerations. First, 64-bit boot media will work with both older BIOS and newer UEFI systems, while 32-bit media only supports older legacy systems (see the troubleshooting box on page 62 for a possible workaround). Second, you need to source portable apps and drivers of the same system type as your rescue disc—32-bit apps are more common than 64-bit ones. Make your choice, then click "Next."

3 CUSTOMIZE PORTABLE APPS

Expand the "File," "Network," and "System" sections to see what bonus tools are included with your rescue disc by default. Select one to read a description. In most cases, you'll leave these all selected—but we recommend deselecting the web browser QtWeb (it doesn't work properly in 64-bit environments).

» Click "Add Files" to add your own portable tools to the rescue disc—up to 2GB of programs can be added this way. It's worth gathering these apps in their own folder, then adding each tool's subfolder individually as shown [Image B]—they'll be accessible from the rescue disc's desktop under the "UserTools" folder. See the box opposite for tips on tools to look for, but remember you can also run portable apps directly off other drives, so long as they're detected by your rescue media, so don't go overboard.





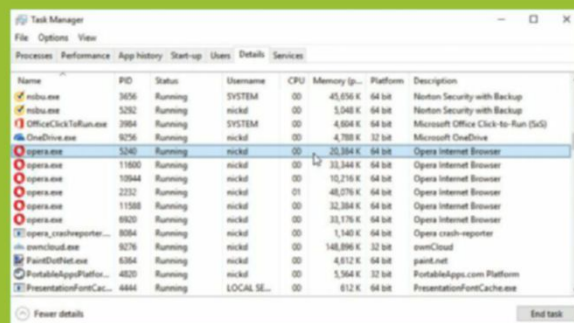
4 ADD CUSTOM DRIVERS

All the core drivers you need—graphics, keyboard, mouse, and wired network—should be covered by PE Builder, but there's a chance that certain network (specifically Wi-Fi) and hard drive (storage controller or RAID) drivers aren't present, while some advanced USB mice and keyboards aren't recognized either. You'll only discover this after you've created (and booted from) your rescue media.

» If you discover missing drivers, you need to source the driver installation files yourself to add them to your recovery media from this screen. First, obtain the latest version of driver from the manufacturer—if you're struggling to track it down, try www.driverscape.com, where you can search a range of popular PC and laptop models, as well as hardware devices.

» You need to be able to extract the contents of whatever driver file you download, so you can locate a .INF file, which is what PE Builder needs to build the driver from. Use a tool such as 7-Zip (www.7-zip.org) to do this—if the file is a setup.exe file, try "Open inside" to see if the driver files can be manually retrieved; if not, you need to look elsewhere for the drivers.

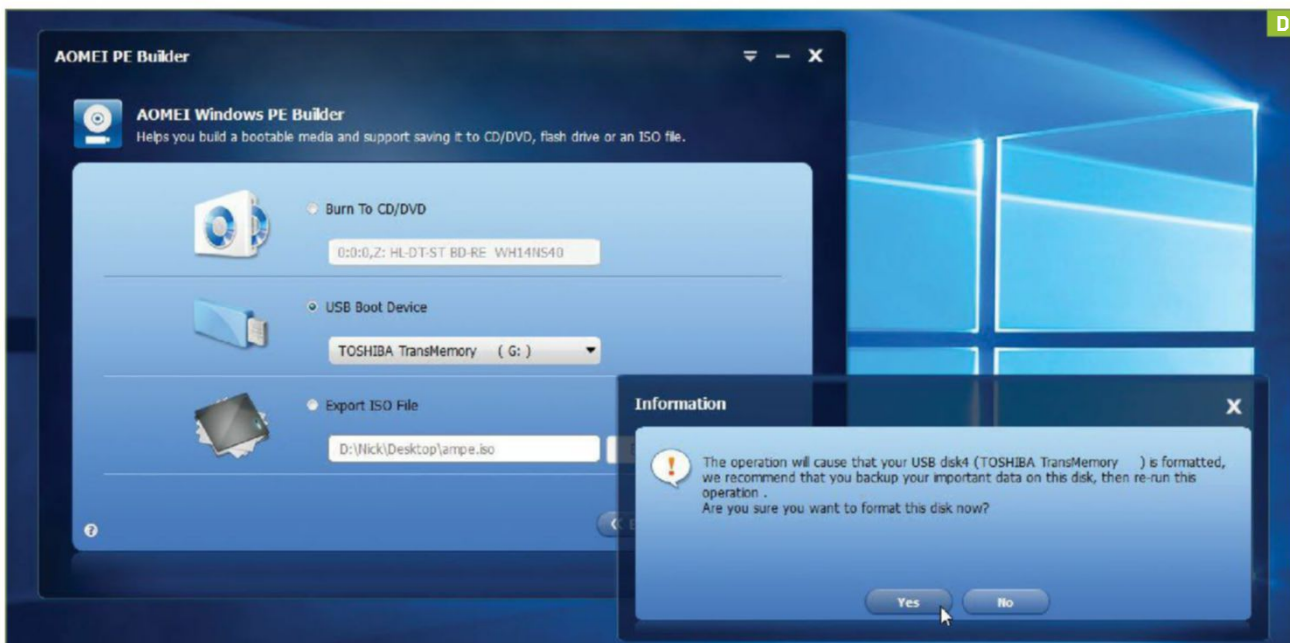
BUILD A TOOLKIT



You can incorporate additional portable tools in your AOMEI rescue disc, giving you access to a wide range of additional apps and utilities. Just one golden rule: Your portable app must match the system type (32-bit or 64-bit) of your rescue disc. To determine this, first launch the app, then open Task Manager. Switch to the "Details" tab, right-click the column headers, and choose "Select columns." Select "Platform," and click "OK." Locate your program, and you'll see it's listed as either 32-bit or 64-bit.

Start your search for portable tools at <http://portableapps.com>, where you'll find most bases are covered, particularly for 32-bit apps. Tools to grab from here include Autoruns (manage startup items), SSD-Z (check hard drive health), Teracopy (faster file transfers), FileZilla (FTP transfers), and PuTTY (SSH into other machines). Visit the programs' home pages to source 64-bit versions.

We also recommend Opera (www.opera.com/computer/portable) to replace QtWeb, data-recovery powerhouse DMDE (www.dmde.com—32-bit only for free version), dual-engine anti-malware tool Emsisoft Emergency Kit (www.emsisoft.co.uk—run it from a separate drive) and O&O RegEditor (www.o-o-software.com) for editing your crashed PC's Registry.



TROUBLESHOOT YOUR RESCUE DISC



If your rescue disc or drive doesn't work as you expect it to during testing, check out these quick-fire fixes.

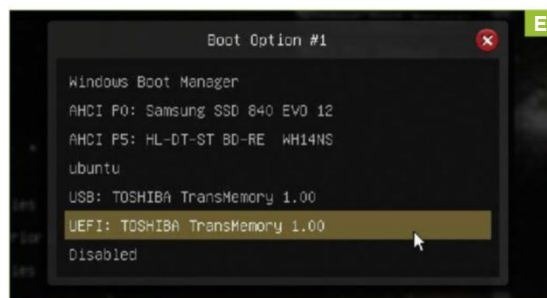
- 32-bit rescue media isn't recognized:** 32-bit media requires an older BIOS-based PC or a newer UEFI PC with Compatibility Mode enabled and Fast Boot disabled. Choose the USB option in the boot menu.
- Insufficient memory error:** PE loads everything it has into memory—if you've not got enough RAM, rebuild your rescue media with fewer tools.
- Computer doesn't boot from USB:** Try burning a CD or DVD instead if your PC isn't capable of booting from USB devices (only the very oldest PCs shouldn't be able to do this).
- Certain hardware doesn't work:** There's no guarantee you'll get your hardware to work, even if you track down drivers. We failed to get two Wi-Fi adapters working (one code 37 error, another driver unrecognized), and our third only worked when we manually installed the driver after booting.
- Program won't run in recovery environment:** Make sure it's the same system type (32 or 64-bit) as your rescue media; also try running from a separate drive.
- I have another problem:** See the FAQ at www.aomeitech.com/pebuilder/help/faq.html.

» If you're able to obtain the files and all-important .inf file, return to PE Builder, and click "Add Drivers" followed by "Add File" to locate and select the .inf file you identified [Image C]. Click "OK" followed by "Next" when you're done.

» If you're attempting to add drivers to your boot media, we suggest taking out an insurance policy by clicking "Add Files" again—this time, click "Add Folder," and add the folder containing your extra drivers to your rescue media. This will enable you to attempt a manual installation of those drivers within the recovery environment, should they not automatically load with your rescue media. Once done, click "Next."

5 CHOOSE BOOT MEDIA

Your rescue disc is now ready to be burned or copied. Select "Burn to CD/DVD" if you have a blank DVD inserted (we recommend rewritable media, because you may find your disc doesn't work, or requires tweaking later). Alternatively, select "USB Boot Device" to choose a flash drive to build the recovery media on—note the drive is completely wiped by this process, so copy off any data you wish to keep from it first. If more than one USB drive is connected to your PC, verify you have the correct one selected by its drive letter. The "Export ISO file" option generates an ISO file you can burn or copy manually, or use in a virtual machine, such as VirtualBox. Click "Next" when you've made your choice. Read any warning [Image D], then click "OK."



6 CREATE DISC

Wait while your recovery media is created—the first time you run the tool, PE Builder downloads a Windows 10 PE installation image, but the file is retained for future use, so subsequent builds should be quicker, unless you switch system type between 32-bit and 64-bit. Once the process is complete, click "Finish."

7 TEST MEDIA

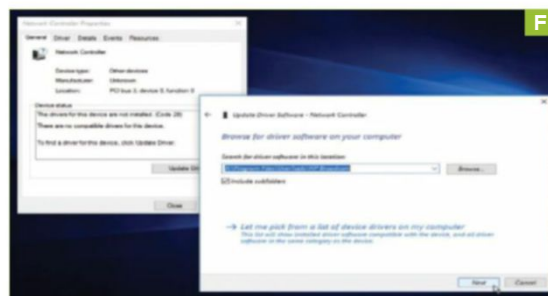
Leave your bootable media inserted and reboot your PC to make sure it works. It may automatically be set to boot from your CD/DVD or USB drive, or you may need to look for an option to press a key—typically a function key—to select your boot device. Once selected, look for your CD/DVD or flash drive. If more than one option is supplied, try the UEFI option first; if that fails, try the USB option [Image E]. If no option appears, or the disc or drive fails to boot, check out the troubleshooting box (left).

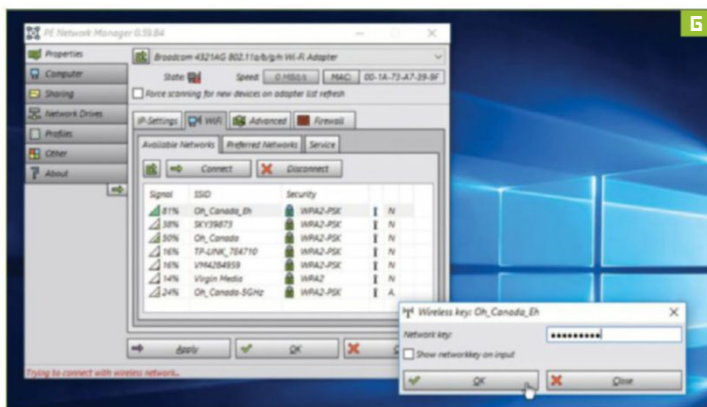
» If successful, be patient—the loading process is much slower than via hard drive, particularly if you've added lots of tools and drivers to your rescue media. Eventually, you should find yourself at the rescue media's desktop, with shortcuts to all the built-in tools. You'll find the resolution is set to 1024x768, which makes it appear squashed on widescreen displays. Sadly, this can't be changed, but it should give you enough room to troubleshoot in.

8 TEST NETWORK CONNECTION

Check to see if you have Internet access through your rescue media. The caveat is that Windows PE only works by default with Ethernet interfaces. Double-click the PENetwork icon to open PE Network Manager. If your Ethernet adapter has been detected, it should be listed. Click the "Info" button to see if it's been allocated an IP address. If it appears to have one, open your portable web browser to verify your Internet connection works.

» If not, click "Renew" if you connect through DHCP, or "Obtain an IP address automatically" to manually set a static IP address, subnet mask (255.255.255.0), and default gateway (the IP address of your router). Set the DNS server to your router's IP address; if that fails, try 208.67.222.222.





9 CONNECT THROUGH WI-FI

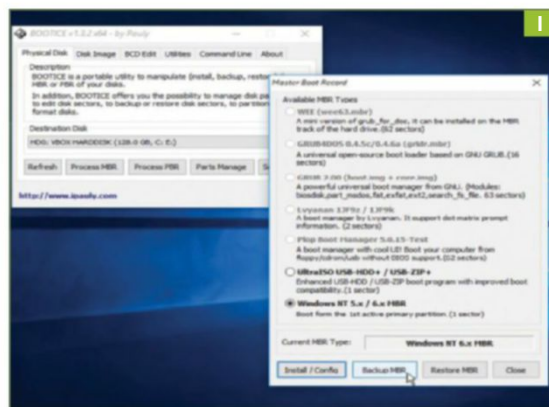
If you're trying to connect via Wi-Fi, click the drop-down menu to see if your adapter has been detected; in the likely event it hasn't, and you've manually added the driver folder to your rescue media (see step four), you can attempt to install it manually. Press Win-R, type "devmgmt.msc," and hit "Enter." Look for a reference to Wi-Fi or Network Controller under "Other devices." Double-click this, then click "Update Driver." Choose "Browse my computer for driver software." Select the folder containing your drivers [Image F], and see whether Windows is able to install them.

» If successful, go to PE Network Manager. Select "Force scanning for new devices on adapter list refresh," switch to the "Wi-Fi" tab, click "Start," then "OK." Reopen the tool, and your Wi-Fi adapter should appear under the device drop-down. Select it, then switch to the "Wi-Fi" tab to connect to your local network [Image G].

10 A BRIEF TOUR

Double-click the "This PC" shortcut in the top-left corner to access File Explorer. You should see all drives (internal and external) appear. If any are missing, you need to source appropriate drivers (typically "RAID" or "storage controller"—consult your PC or motherboard's support site for them) to add to your rescue media. You'll notice a drive marked "X"—this is the drive Windows PE has installed itself to, and is a "virtual drive," in that it's stored in RAM. This is partly why it's restricted to 2GB, to work on lower memory (and 32-bit) machines. Your other drives should be recognizable by their drive letters—though some may have swapped around, so browse each one for confirmation.

» In case you ever find yourself using your rescue media to try to recover from a non-booting PC, now would be the time to work out which drive is your backup drive, then launch AOMEI Backupper from its desktop shortcut to take a full backup of your afflicted Windows system drive [Image H]. This would enable you to then attempt repairs knowing your files are protected, should you be forced to perform a complete wipe and reinstall.



11 TEST YOUR APPS

Open the "UserTools" folder via its shortcut to test any apps you've added. Not all will work, even if they are the correct system type. Non-functioning apps usually exhibit no symptoms—you double-click the shortcut, but nothing happens, even after a wait (right-click the Taskbar and choose "Task Manager" to see if anything is present).

» Some apps fail because they prefer to run from a physical drive—if you have a portable apps folder on another drive, try running them from there. There's no rule—other than convenience—that forces you to incorporate your apps into your rescue media.

12 QUICK-FIRE TIPS

There are no quick-and-easy repair tools built into the AOMEI rescue media—you may want to pair it with a Lazesoft Recovery Suite Home Edition recovery disc (www.lazesoft.com) to cover all bases. The PE environment is best used for backing up and recovering data, browsing the web to troubleshoot boot-related problems, and perform manual repairs. Built-in tools that can help include AOMEI Partition Assistant (recover lost or deleted partitions), BootICE (examine and repair boot entries), and Recuva (recover deleted files). You also have access to a limited set of system tools—press Win-R to launch Control Panel (control.exe—most links don't work, however), Device Manager (devmgmt.msc), or Computer Management (compmgmt.msc), among others [Image I].

» One major thing to remember is that you're not directly plugged into your Windows installation. That means taking additional steps to connect to files and settings associated with your ailing Windows install.

» For example, to view and edit your BCD file on an older PC, with a BIOS rather than UEFI, you need to direct BootICE to the system reserved partition's Boot folder, and the Bcd file within. To manage your PC's startup entries in Autoruns, choose "File → Analyze Offline System," and point "System Root" to C:\Windows, and "User Profile" to C:\Users\<Username>. Finally, editing your Windows Registry using O&O RegEditor would require you to point the program at C:\Windows. Replace "C:" with whatever drive your Windows installation is on.

» Any changes you make to any apps incorporated in your rescue media are lost when you reboot, so while you might want to synchronize your Opera profile with the portable app to access your favorites and add-ons, for example, you'd need to do so every time you booted from the rescue media. To get around this, use portable apps stored on another drive, where changes are recorded.

WolfenPi: FPS Action in WWII

YOU'LL NEED THIS

WOLFENSTEIN 3D

The game can support gamepads, such as PS3 controllers. See <https://goo.gl/VHLYd> for more information.

RASPBERRY PI

Any version should be OK, but a Raspberry Pi 3 is recommended for the best performance.

SECRET AGENT Captain William "BJ" Joseph Blazkowicz's commendable efforts to halt the Nazi war machine come to a crashing halt at the start of id Software's *Wolfenstein 3D*. Having successfully thwarted an evil scientist's plans to create a race of mutant-Nazi hybrids, BJ has been captured and consigned to the dungeons of the Nazi stronghold, Castle Wolfenstein. After quickly overpowering a hapless guard, you must now navigate BJ through the six episodes of the game, consisting of 10 levels each, shooting evil henchmen and dogs, while collecting looted treasure on the way.

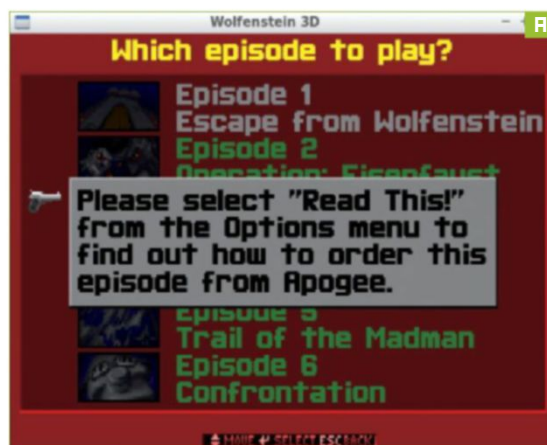
While using Nazis as bad guys is nothing new, when *Wolfenstein 3D* was first released in 1992, even its developers couldn't have known the staggering level of success it would enjoy. At its heart, the game is a first-person shooter, using 3D graphics in the style of *Doom*, which id Software would release a few years later. The game is notable for its use of ray casting, a technique whereby only surfaces closer to the player were calculated, resulting in much smoother gameplay. This, of course, was an issue much more relevant to users of early '90s PCs, but it's also important to your gaming experience on the Raspberry Pi. —NATE DRAKE

CHOCOLATE WOLFENSTEIN

Apart from being both a showcase for the first-person shooter and shareware, *Wolfenstein 3D* was also notable in that its developer licensed the game engine to other companies. This resulted in the game being ported to various other platforms besides the original MS-DOS, such as Mac OS, the Acorn Archimedes, and SNES. In 1995, the source code for the *Wolfenstein 3D* game engine was released, which meant that fans were now free to create their own versions.

» In this guide, we're focusing on running Fabien Sanglard's formidable Chocolate Wolfenstein engine. This is a slightly improved version of the original "vanilla" engine, which is nevertheless designed to mimic the original game as closely as possible.

» Although the engine itself is open source and can be compiled on your Pi, the game data files, which contain details of maps, levels, enemies, and so on, are still under copyright. For this reason, this guide focuses on running the shareware version of *Wolfenstein*



WILL THE "REAL" WOLFENSTEIN PLEASE STAND UP?

If you install the Steam version of *Wolfenstein 3D* for Windows, navigate to "C:\Program Files (x86)\Steam\steamapps\common\Wolfenstein 3D\base" and copy all nine files with the extension ".wl6" on to a USB stick, then insert it into your Pi. The files and extensions must all be in lower case to be compatible. Open Terminal, and navigate to the USB stick—for example, `cd /media/pi/USB1`. Convert the files to lower case with `for i in $(find . -type f -name "[A-Z]*"); do mv "$i" "${echo $i | tr A-Z a-z}"; done`. Finally, move them to the correct folder with `mv *.wl6 /home/pi/Chocolate-Wolfenstein-3D/`.

Next, run the command `sudo nano /home/pi/Chocolate-Wolfenstein-3D/`

`version.h`. This file determines which version of *Wolfenstein* to compile. Find the section marked "/* Defines used for different versions */" and make sure there's a `//` at the start of every line in that section, except those containing the words "GOODTIMES" and "CARMACIZED."

Press Ctrl-X, then Y, then Return to save and exit. Follow the steps in the walkthrough on the right to compile the full version of *Wolfenstein 3D*.

If you've purchased the prequel, *Spear of Destiny*, the data files are located in "C:\Program Files (x86)\Steam\steamapps\common\Spear of Destiny\base" and have the extension .SOD. Change these to lower case and move them into the "Chocolate-Wolfenstein-3D" folder as

```
GNU nano 2.2.6 File: version.h
#define _VERSION_H_
#define _VERSION_H_

#ifndef VERSIONALREADYCHOSEN // used for
/* Defines used for different versions */
// #define SPEAR
// #define SPEARDEMO
// #define UPLOAD
#define GOODTIMES
#define CARMACIZED
// #define APOGEE_1_0
// #define APOGEE_1_1
// #define APOGEE_1_2
/*
Wolf3d Full v1.1 Apogee (with ReadThis) - defl
Wolf3d Full v1.4 Apogee (with ReadThis) - defl
```

outlined above. Run `sudo nano /home/pi/Chocolate-Wolfenstein-3D/version.h` and make sure there's a `//` at the start of each line in the same section, except those containing the words "CARMACIZED," "SPEAR," and "GOODTIMES."



3D on your Raspberry Pi, which contains only the first episode, “Escape from Castle Wolfenstein” [Image A]. This still gives you 10 levels of high-octane, chaingun-smoking action, but if you want to play the full version, you can purchase the game, and copy the data files over to your Pi if you wish. The Chocolate Wolfenstein engine also supports playing the prequel to *Wolfenstein 3D*, called *Spear of Destiny* (see the boxout, below-left).

2 PREP YOUR PI

Although, technically, you can compile and run Chocolate Wolfenstein on any model of Pi, we recommend using a Raspberry Pi 3 for best performance. The tutorial assumes you have a clean installation of Raspbian on your SD card, and that you have run `sudo apt-get update` and `sudo apt-get upgrade` before going any further.

3 ATTENTION TO DETAIL

Because the Chocolate Wolfenstein engine only requires you to run the `make` command, and place the data files in the same folder as the executable, there’s very little that can go awry with this project. Data files for different iterations of *Wolfenstein* games have different extensions, such as the shareware version of *Wolfenstein 3D* (.wl1), the full version (.wl6), and *Spear of Destiny* (.sod). If you see an error message when trying to launch the game, saying it can’t find the right data files, the most likely reason is because all data filenames and extensions must be in lower case—this process is initially done in the boxout on the left.

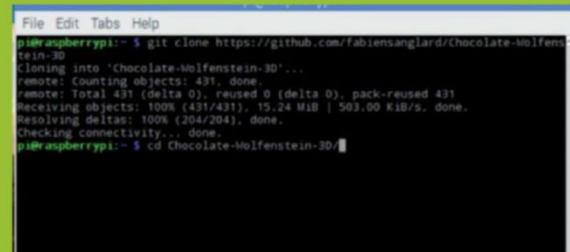
» The Chocolate Wolfenstein 3D engine also has to be compiled differently, depending on the version of the game that you’re using. You can change this in the “version.h” file in the game directory.

4 GAME OPTIONS

If you don’t know how to get the data files for the full version of the game, consider buying the Steam Windows version of *Wolfenstein 3D* [Image B], which is available for \$5. See the boxout on the left for help with finding the data files for installation. Steam also sells a Windows version of *Spear of Destiny* for \$3. Non-Windows users may be able to find a second-hand version of the game CD online.

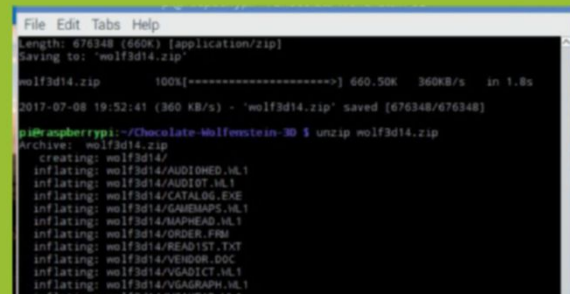
» If you enjoy the premise of gunning down Axis troops but aren’t happy with the clunky graphics, you’ll be pleased to know that the game spawned the free and open-source Linux game *Wolfenstein: Enemy Territory* (www.splashdamage.com/content/download-wolfenstein-enemy-territory). The game gives you the choice of fighting on the side of either the Axis or Allied powers, playing as part of a multiplayer team with your friends. ⚡

WOLFENSTEIN 3D ON YOUR RASPBERRY PI



1. INSTALL PREREQUISITES

Open Terminal on your Pi, and run `sudo apt-get install cmake libsdl1.2-dev libsdl-mixer1.2-dev libsdl-net1.2-dev libbz2-dev libjpeg-dev libgtk2.0-dev`. Next, run `git clone https://github.com/fabiensanglard/Chocolate-Wolfenstein-3D` to download the Chocolate Wolfenstein engine. Move to the directory with `cd Chocolate-Wolfenstein-3D`. Compile the code by running `sudo make`. This creates an executable: `Chocolate-Wolfenstein-3D`.



2. DOWNLOAD DATA FILES

Run `wget http://maniacsvault.net/ecwolf/files/shareware/wolf3d14.zip`, then `unzip wolf3d14.zip` to download and unzip the shareware version’s files. Change over to the directory using `cd wolf3d14`. Next, run `for i in $(find -type f -name "[A-Z]*"); do mv "$i" "${echo $i | tr A-Z a-z}"; done`, then relocate the data files to the game directory with `mv *.wl1 /home/pi/Chocolate-Wolfenstein-3D`.



3. LAUNCH WOLFENSTEIN 3D

Use `cd ..` to switch to the main game directory. The shareware version of *Wolfenstein 3D* can be launched any time by entering `./Chocolate-Wolfenstein-3D`. Add the parameter `--res 640 480` or similar to adjust the screen resolution. See <https://github.com/fabiensanglard/Chocolate-Wolfenstein-3D/blob/master/docs/README.Wolf4SDL.txt#L81> for a full list of command-line parameters.

Edit Your Images in Luminar

YOU'LL NEED THIS

LUMINAR

Grab the beta or full version from <https://macphun.com>.

IMAGES

You need a photo or two to edit.

NOT EVERY IMAGE-EDITING APP has to be by Adobe, and sometimes something comes along from an unexpected source that's genuinely interesting, and trying to do something new.

One such program is Luminar, from Macphun. The clue is in the developer's name—this app has been available on fruit-based computers for a while now, and as was the case with Affinity Photo, this means the minimalist architects and latte-drinkers have done the beta testing for us. At the time of writing, Luminar is available for free download as a Windows beta, but by the time you read this guide, it may be available as a full release—the launch date is currently down as the rather nebulous “fall 2017.”

Luminar isn't Photoshop; it's more a collection of one-shot fixes and presets, but it has the ability to alter these effects, and layer them on top of one another, to build up sophisticated results, with a before and after slider so you can see precisely what you've changed. —IAN EVENEDEN



1 GET SET

As we write, you can get the beta version of Luminar from <https://macphun.com>, but that will change as soon as the developer presses the big green “Go!” button, and launches the app. Once it's up and running, you're offered the choice of working on your own pictures or on a sample image. The sample shots are very good, and provide a playground in which to try out all aspects of the app, but there's nothing like editing your own work, especially with the trees giving such a fine display of fall color.

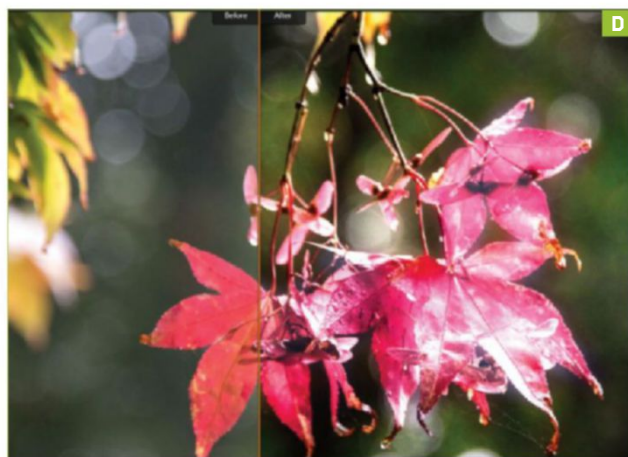
2 PLAY WITH YOUR PICTURE

Open an image using the folder icon to the top-left of the interface, and after a little processing, you'll see previews of your image in all the presets along the bottom of the app. Clicking the “Infinity” button to the extreme-right opens up the categories of preset, so you can narrow down your search for a good look. We

discover there's one called “Colors of the Fall,” so apply it to our image, and click the divided rectangle icon at the top-middle of the window to enable a before and after view [Image A] that can be dragged back and forth to show the effect the adjustment has. The eye button next to it returns your image to its unaltered state for as long as it's held down, and there are zoom and full-screen controls to the left of the eye.

3 OOPS—TRY AGAIN!

With a preset selected, a column of adjustments appears on the right, so you can tweak the parameters of its effects. They're worth experimenting with, so you can get a handle on what they all do—Luminar offers non-destructive image editing, so no changes are final until you export your work as a new image. There are



also many ways to undo your work, with a “Reset” button appearing above (or below) every slider in the right-hand column, a big single-click “Undo” arrow at the top of the interface, and a clock icon next to it that drops down a “History” menu [Image B], so you can go back to a particular stage in your workflow and restart from there.

4 ROLL YOUR OWN

One of the more interesting presets is the “Auto Smart Enhancer,” which analyzes your image to decide how best to enhance its tones and contrast [Image C]. It’s not worth buying an app like this just to use it as a one-click-fix machine, however, but it does provide a good starting point for you to take control and adjust the image manually. Seeing how the ASE has manipulated the sliders in the right-hand column gives you a good idea of how they work, and you can push some of them further or pull them back to create something more in keeping with your own preferences. You can then save your settings as a new custom preset, so you can come back to them when working on subsequent images.

5 ICONOCLASTS

Luminar’s layers are one of its strongest features, enabling you to place separate effects on top of one another, and then fade the top one out, so they blend together. The “Layers” palette can be accessed from the icon, top-right, which looks like two overlapping squares, if it’s not visible already—one of the weaknesses of Luminar’s interface is the way icons are spaced out along the top bar, and the lack of explanatory tooltips when you

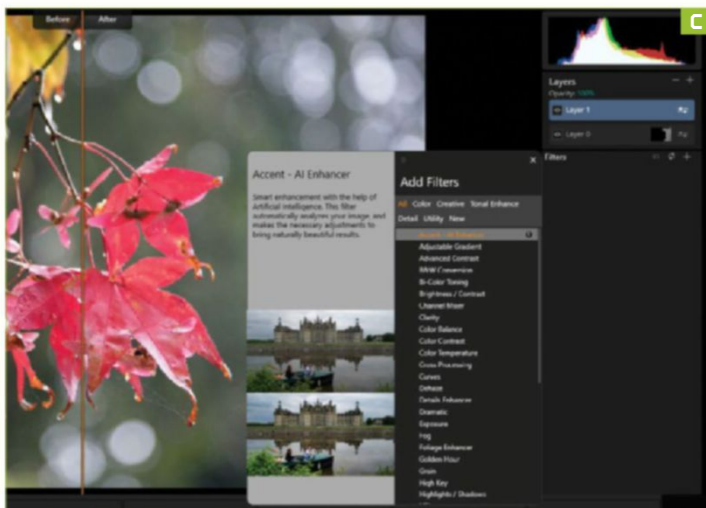
hover your pointer over them. Hopefully, this can be fixed in the final release.

6 LAYERS AND MASKS

In addition to layers, you can use masks to apply an effect to only certain areas of an image. Luminar has rectangular and circular gradient masks, and a paintbrush tool that enables you to paint your chosen preset or filter on to your image. This is especially useful when combined with layers, because you can have one set of presets applied to the base layer, with another set painted on to an upper layer, completely changing the look of the parts it affects [Image D].

7 CROP AND GO

When you’ve finished with your editing, there are two steps you can take. There’s a crop tool hidden away on the extreme-right, looking like a pair of scissors. Use this to trim away the edges of your image to change its center point or aspect ratio—you can use it to rotate, too, if you’ve got a tilted horizon, or other lines that should be straighter. Then there’s the “Export” button, at the top-left, looking like a square with an arrow pointing out of it. This enables you to save your work as a file locally, and also share straight to social media or email. You’re not given a huge choice of formats to export to, but a straightforward JPEG is usually all you need. 🔄



FILTER YOUR MEDIUM

Filters—different from presets, in that they do one thing only—can be accessed by popping out the menu at the top of the “Filters” stack on the right, using the “+” button. You get an explanation of what each one does, which is an improvement over the presets, as you don’t have to guess what they do based on the thumbnails at the bottom. If you want more space for your image, this thumbnail bar can be turned off, using the controls at the top-right, along with the more useful right-hand adjustments column. Curiously, presets are applied at 1,000 percent, and you turn them down to your liking, while filters are applied at 0 percent, requiring you to turn them up.

Manage Your Music

YOU'LL NEED THIS

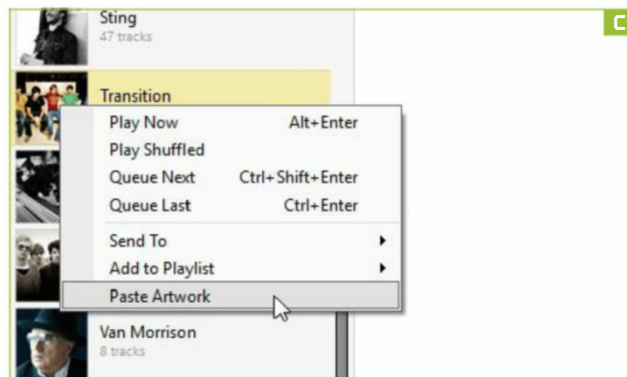
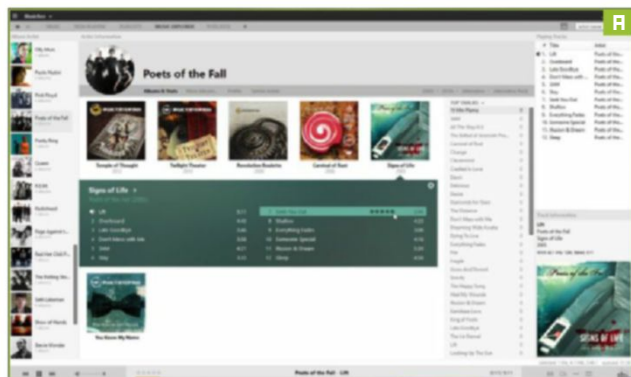
MUSICBEE

Download the free music app from www.getmusicbee.com.

THERE ARE SO MANY PLACES TO GET MUSIC—you can rip it from CDs, download it directly from the artist, buy it in an online store.... It's brilliant to have so much choice, but it's easy to end up with a huge collection of music that's impossible to organize and manage. Incorrectly labeled songs, duplicated files, and missing artwork all make it difficult to find and enjoy the library that you have spent years assembling.

That's why you need MusicBee. This amazing free music software can handle just about every audio file format there is (including FLAC and WMP), and it works with some high-end audio cards.

Crucially, MusicBee can also help organize even the biggest and messiest of music archives. It can tag your songs automatically, remove duplicates, fix split albums, find cover art, and even track down song lyrics. To top it all off, MusicBee is also a brilliant music player. Once you try it, you'll never want to use anything else. —CAT ELLIS



1 GET MUSICBEE

Go to www.getmusicbee.com and click the "Download now" button to fetch the MusicBee app. Once its ZIP archive has been saved to your PC, extract the contents, and double-click the EXE file to run the installer. Accept the default options, then leave "Run MusicBee 3.0" checked, and click "Finish." Select your preferred language, and the program opens for the first time [Image A].

2 IMPORT YOUR MUSIC

Now you need to tell MusicBee where to find your music. The software can automatically import songs and album artwork from Windows Media Player or iTunes, or scan your PC for songs. By default, it looks in the public Music library on your PC, and in your own library. If you keep your music in other locations (on a connected

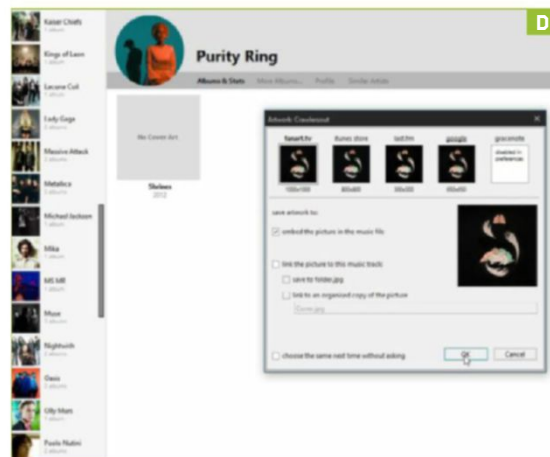
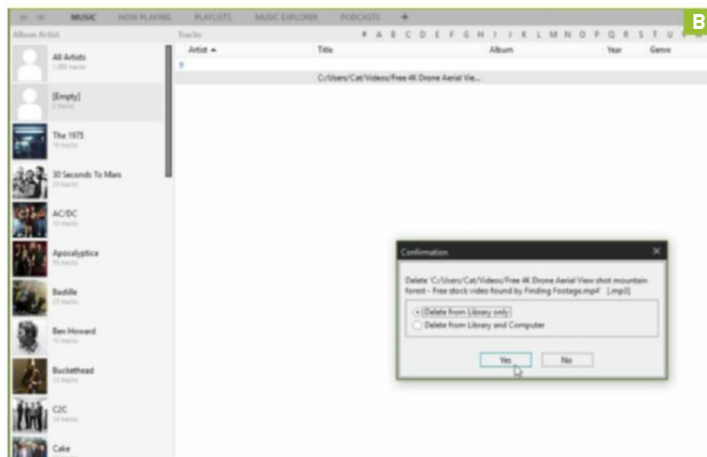
external drive, for example), click "Choose folders," and select them.

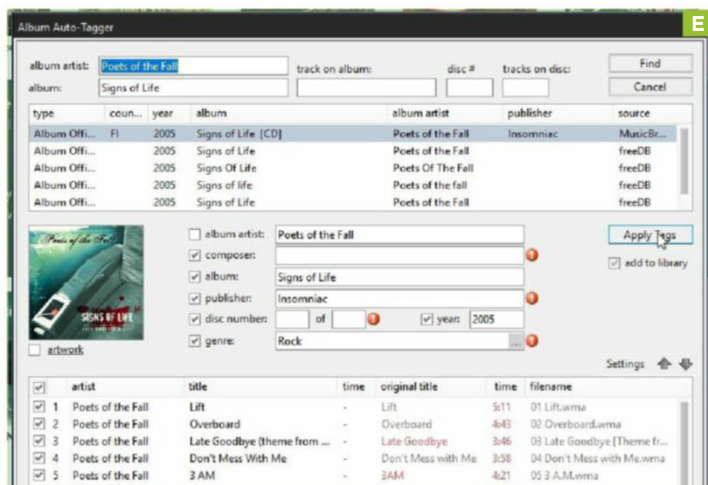
3 CHECK YOUR FILES

Click "Scan now," and MusicBee finds all the audio files in those folders, and organizes them by artist. If a file has no metadata, it appears at the top under "[Empty]." It might be an incorrectly labeled song, or other audio file. Click to find out. If it isn't a song, right-click it, and select "Delete → Delete from library only" [Image B].

4 UPDATE ARTIST IMAGES

MusicBee automatically searches for an image of all the artists in your music library. If one of the





artists doesn't have a photo (or the photo is wrong), find a suitable image online, and copy it to your clipboard, then right-click the artist in MusicBee, and select "Paste artwork" [Image C]. Now it's time to take a look at your albums. Click the "Music explorer" tab in the gray bar at the top.

5 GET ALBUM ART AUTOMATICALLY

Select an artist to see the albums you own. Some of these may also be missing artwork. If that is the case, you can either paste it in like before, or right-click the empty square, and select "Search Internet for picture." Leave "Embed this picture in music file" selected [Image D], so it isn't lost if you decide to change to a different music player at a later date.

6 FIX INCORRECT TAGS

Sometimes you might come across an album that MusicBee doesn't recognize. Unless it's a very rare or esoteric work, and very few people are likely to own it, it has probably just been tagged incorrectly. Right-click it, select "Auto tag by album," and several options should appear. You need to select the one that matches the music you own, but be careful—it isn't necessarily the first one on the list [Image E].

7 GET THE RIGHT INFO

At the bottom of the track details window, you'll see two sets of information—one in black, and one grayed out. The information in gray is the original metadata attached to the album, and the information in black is what will replace it. You want to

select the option from the auto-tagger list that's the most accurate. When you're satisfied, click "Apply tags."

8 JOIN SPLIT ALBUMS

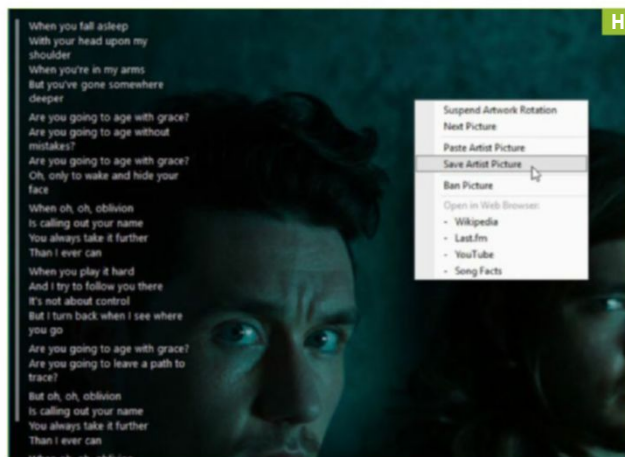
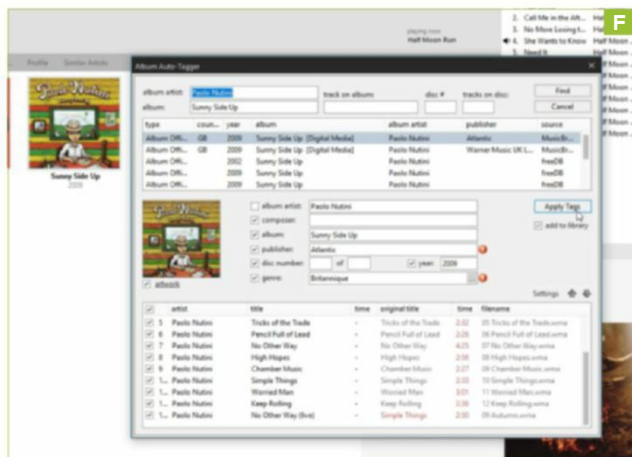
Occasionally you'll come across an album that's split [Image F]—iTunes is notorious for causing this. Click one album, hold Ctrl, click the other, and select "Auto tag by album." There should be an option to combine them. If the change doesn't happen immediately, select a different artist, then go back to refresh the library.

9 GET SONG LYRICS

Double-click an album to start playing it, then click the "Now playing" tab. MusicBee finds high-resolution pictures of the artist, and uses them to create a slideshow that you can watch. It also tries to find lyrics for the current song. If you can see that the lyrics aren't correct, right-click them, and choose "Search next provider" or "Edit displayed lyrics" [Image G].

10 MANAGE SLIDESHOW IMAGES

If a picture you particularly like appears in the slideshow, right-click it, and select "Save artist picture" [Image H]. Similarly, if a picture appears that isn't of the artist, or you don't like it, you can select "Ban picture." Congratulations—your music library is now much more organized, with correctly tagged albums, artwork, lyrics, and photos. Happy listening!



BUILD IT

ZAK STOREY, DEPUTY EDITOR



Mid-Range AMD Gaming Rig

So, this is what going all red on a budget of just over 1,000 bucks looks like

LENGTH OF TIME: 1-2 HOURS

LEVEL OF DIFFICULTY: **EASY**

THE CONCEPT

WE HAVE a bad habit of focusing too much on the high end, and not enough on what really matters. Say what you like, but the halo products aren't what make or break a company. And although manufacturers make their biggest margins on the most expensive components, it's the mid-range and budget sections of the spectrum that secure the most market share. Which is why, more often than not, they're the more interesting products. Ask any of our team which processor interested them the most over the last two years, and the answer almost always falls down to either the Pentium G4560 or the Rvzen 3 1200.

Anyone can spec out a high-end, pixel-crushing, calculation-solving monster. But it takes a true master to get the most out of a tighter budget. Every dollar counts—far more so than with the inefficient price-hiked parts of the high-end machines. And that's what we wanted to look at this time around. The concept was simple: Take a \$1,100 budget, pick mid-range components, and come out with a solid, fun, and fast 1080p gaming machine, using AMD parts for the GPU and CPU.

The Ryzen 3 1300X was the base for this build. After numerous high-priced systems, it was nice to get a little more down to earth with a budget part, a stock cooler, and some neat money-saving ideas, without losing out on the speed we associate with systems that can cost twice the price of this one.



CHOICES, CHOICES

WE'VE BEEN ITCHING TO TRY out this case for a while. Phanteks' P300 case is an astonishing achievement of budget-busting ingenuity. Featuring tempered glass, RGB LEDs, a sophisticated internal chassis design, PSU cover, dust filters, room for 280mm AIOs, and extensive storage support, this beautifully crafted case comes in at just \$64. Honestly, it's almost impossible for us to recommend any other chassis at this price point right now. Regardless of your budget, it's simply too good.

As we said, we decided to go with the Ryzen 3 1300X as our base; a quad-core part, with enough grunt to pump through AAA titles with ease, especially at that 60fps sweet spot. On top of that, we added Gigabyte's Aorus Radeon RX 570 refresh. With higher clock speeds and 4GB of VRAM, it'll make quick work of any of our 1080p titles, and look pretty flashy while doing it. Its compact size also helps with the build, because it doesn't look as though we'll run into any clearance issues with it.

Amazingly, under full load, this system should draw an estimated 326W from the wall at most, so we opted for a non-modular 500W Bronze PSU from Corsair. Although we don't intend to overclock our Ryzen chip, having the extra headroom is useful in case we change our minds later down the line, and also helps if we ever decide to upgrade to a beefier GPU.

For storage, we stuck with that old staple of the modern system: a 120GB SSD for the OS and a 1TB-plus (in our case, 2TB) HDD for everything else. Samsung's 120GB 750 Evo comes in at a reasonable \$78, and provides a perfect platform for this build, while the WD Black is more than enough for our gaming needs.

INGREDIENTS

PART		STREET PRICE
Case	Phanteks Eclipse P300 ATX Mid Tower	\$60
Motherboard	Gigabyte GA-AB350-Gaming 3	\$109
CPU	AMD Ryzen 3 1300X	\$127
Memory	16GB [2x 8GB] Corsair Vengeance LPX—2666	\$180
GPU	Gigabyte Radeon RX 570 Aorus 4GB	\$259
PSU	Corsair CX500 500W 80+ Bronze PSU	\$44
Storage 1	120GB Samsung 750 Evo 2.5-inch SSD	\$78
Storage 2	2TB WD Black Series 7,200rpm HDD	\$119
Cooling	Stock	Free
OS	Windows 10 Home	\$90
Total		\$1,066

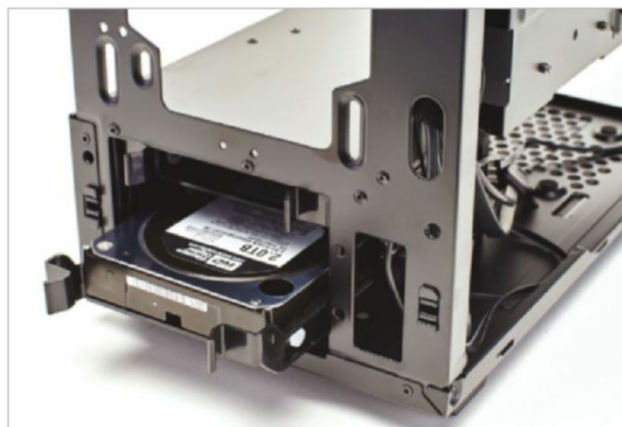
1 TEST TIME

WE DON'T SAY THIS often enough: For most new builds, to save time and effort, it's best to test most of your components outside the case. A good way to do this is to build your system on top of the box the motherboard came in. The cardboard box acts as an anti-static test bench, and by testing it outside the chassis, if you have a problem with the motherboard, CPU, or anything else, you can quickly resolve the issue with the supplier, without having to rip everything out of your system. Word of warning: Do not place your motherboard or GPU on top of the anti-static bags they came in, because the outside of the bags actually conducts electricity.



2 HDD INSTALLATION

THE NEXT STEP for any build is to strip the case down as far as you can, removing all the side panels, the roof, and the front covers if possible. In the P300's case, once you do this, you gain access to the hard drive cages, because they pull out from the front of the chassis. Make sure you install the hard drives with the connectors facing backward—toward your power supply—and you shouldn't have too much of an issue. Some hard drives may not fit in the stock caddies, so you might need to get inventive with the toolless mounting (we had to remove the two clips, and secure ours with screws).



5

A close-up photograph of a SATA-to-USB adapter. The adapter is a small black circuit board with a SATA connector on one end and a USB connector on the other. It is connected to a SATA drive (partially visible) and a USB cable. The background is dark and out of focus.

6

6



- 1 **Tasteful LEDs? Say it isn't so!** This tiny LED strip light can be configured by the front I/O, and streaks down the side of the tempered glass panel.
- 2 **The only thing we do wish is that this PSU cover had some cutouts,** so the GPU power could run straight through, as opposed to sideways.
- 3 **Adding an additional 120mm fan in the front here would help keep temperatures down immensely,** providing cool air to the GPU.
- 4 **You could run an M.2 SSD beneath the GPU,** but to avoid thermal throttling, you're better off with the 2.5-inch in the back.

RED PLANET

THIS IS ONE classy machine. It just goes to show how far chassis development has come—the internal layout enables you to keep budget boxes so much tidier nowadays.

All in all, it was a painless build. The only real issue we had was with the hard drive caddy. Why the mounting slots don't match the holes in WD's 2TB Black 3.5-inch drives is beyond us. We got around this, though, by removing the two toolless clips from the caddy, then securing the hard drive in place with screws instead. It was also tricky to install the cables. We actually slid it out the front, installed the cables through the case, then slid it back into the hard drive cage. Having the extra wiggle room outside the chassis made it easier.

We had a slight issue when installing the motherboard, and it was nothing to do with forgetting the rear I/O shield either. Whether it was a cost-cutting measure in the P300, or the B350-Gaming 3's budget sizing, there were no cut-outs to support the extreme right-hand edge of the motherboard. So, if you weren't careful, you could accidentally flex the PCB when installing the 24-pin ATX power. To get around this, when installing the big juice, we placed two fingers underneath the edge of the board, before pushing the 24-pin into place. Interestingly, the P300 supports E-ATX boards, but only up to 275mm—impressive nonetheless, and an oddity in a \$60 chassis.

On to the nitty gritty: performance. It isn't a bad rig at all. The Ryzen 3 1300X is a potent chip for the price. Desktop performance

is smooth as butter, combined with 16GB of DDR4, and that zippy 750 Evo is quick, too, and doesn't bottleneck when running multiple applications. Now, we're not saying you can have 15 Chrome tabs open, VoIP, two games, and screen recording on the go, but for everyday usage, office work, or more, it hits the spot perfectly. In game, it holds itself steady, hitting 54fps in *The Division* at 1080p, and 30fps in *Rise of the Tomb Raider*, at the nastiest of settings. The RX 570 isn't the most cost-effective card currently available, we have to admit—and as cryptominers continue to snap up any AMD-branded card, that's

unlikely to change anytime soon—but it's no slouch either. Perfect for 1080p gaming.

The upgrade path for this rig is fairly sound. A more powerful processor would be a treat, or to save a bit of dollar, you could invest in the cooling, and overclock the 1300X. Higher frequency memory makes a huge difference to Ryzen's performance, too—a 3,200MT/s kit would easily add 10–15 percent to processing output. Of course, the obvious hit for gamers right now is that Nvidia is far more cost-effective than the AMD alternative. It's a good rig, for sure, we just wish AMD's VGA division was a little more competitive. ⚙️

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi-Thread	987	543 (-45%)
Cinebench R15 Single-Thread	196	137 (-30%)
TechARP's X264 HD 5.0.1 (fps)	21.93	12.23 (-44%)
CrystalDisk QD32 Sequential Read (MB/s)	1,895	519 (-73%)
CrystalDisk QD32 Sequential Write (MB/s)	949	483 (-49%)
Rise of the Tomb Raider (fps)	41	30 (-27%)
The Division (fps)	78	54 (-31%)
3DMark: Fire Strike (Index)	15,026	9,772 (-35%)

Our desktop zero-point PC uses a Core i7-6700K CPU @ 4.6GHz, an AMD R9 Fury X, and 32GB of RAM. All games are tested at 1080p on max settings, with HD texture packages installed.

We've upgraded

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REVIEWS

TESTED. REVIEWED. VERDICTIZED.

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An eye-watering price, but it is an exceptional motherboard.

MSI Z370 Godlike Gaming

Coffee Lake perfection

WHEN COFFEE LAKE first launched, it's fair to say we were fairly apprehensive of the azure juggernaut's response to Ryzen. After all, it came out of the blue. Kaby Lake officially launched in January 2017, and a meager nine months later, we gained its hex-cored successor. And there was a big problem: thermals. At first glance, Coffee Lake's six-core flagship seemed nothing more than a hot-headed retort, an attempt to regain the lost ground Ryzen had claimed. Although impressive, with both price and performance being perfectly on point, skyrocketing past its predecessors, its thermal dynamics really put us off.

Our launch sample came with an Asus Maximus X Hero motherboard, almost identical to the one we received with the Ryzen launch. No cause for concern there. However, temps were through the roof, reading 70–80 C at stock under load, with a 280mm AIO chilling the six-cored critter. At first, we chalked this up to the thermal paste between the die and the IHS still being the same poor quality crud used since the launch of Ivy Bridge, back in 2012.

But once we began to dig below the surface, it soon became apparent that this wasn't the case. There was an issue with voltage. Even with the latest BIOS installed, the Maximus X Hero's VCore was fluctuating between 1.3 and 1.4V. Now, by default, your standard Sky Lake chip ate its way through

1.2V at stock, yet it was possible to easily get it running, stable, at 1.12V with little issue, reducing load temperatures by around 10 degrees in the process. However, synthetic and real-world benchmark scores were high on the Maximus, and the architectural design effective, so we put it down to a generational quirk, with the additional cores simply requiring more juice.

GODSPEED

In comes the MSI Z370 Godlike Gaming. Our second Z370 board on test, and the difference couldn't be more dramatic. At stock, there's just a small disparity (less than 5 percent) between our benchmark scores, both in synthetic and real-world tests. And that alludes to how this motherboard applies its VCore voltage. In other words, it does it right. At stock, we noticed a maximum 1.1V being pumped into the VCore, with very little in the way of V-Droop. At 1.3V, we even managed a concrete 5GHz across all cores, bumping those figures up comfortably to Ryzen 7 1800X levels of performance, but at a far lower cost with regard to temps.

That, however, is beside the point. This is a \$500 motherboard—and, boy, can you tell. It is absolutely packed to the brim with practically every feature MSI could fit on a board. Its E-ATX bulk houses support for three M.2 PCIe SSDs on the board itself,

with an additional two via an add-in card. It features triple Gigabit Ethernet ports, with 5GHz Wireless A/C. For connectivity, you're gifted with 7x USB 3.1 Type A ports, one USB 3.1 Type C port, and a combi port. Then, of course, we get to the audio. And, damn, is it juicy. Featuring an ESS Audio DAC, with its own dedicated amplifier, hi-fi grade WIMA capacitors, and dual (both front and rear) HD audio processors, the Godlike sounds stunning. It even has separate isolated PCB layers, unique to each left and right channel. Couple that with gold-plated 5.1 audio, optical out, and a full-size 0.25-inch headphone jack, and it's enough to satisfy any audiophile.

The Godlike Gaming is a true testament to exactly what you can fit on the Z370 chipset. Its impressive design, clean aesthetics, dependable audio, and appropriate performance make it one of the best motherboards we've ever seen from MSI. And if this is any indication of how the rest of MSI's lineup performs this generation, call us impressed. This is Coffee Lake done properly. —ZAK STOREY

VERDICT

9

MSI Z370 Godlike Gaming

ODIN Correct voltage management; solid

overclocking; clean aesthetic; extensive expandability; incredible networking; premium audio; no auto-overclocking.

LOKI Price; price; price.

\$500, www.msi.com

BENCHMARKS

	MSI Z370 Godlike Gaming	Asus ROG Maximus X Hero
X265 Benchmark (fps)	28.32	30.65
Cinebench R15 Multi (Index)	1,422	1,553
Fry Render (Seconds)	142	133
AIDA64 Memory Latency (ns)	48.9	48
Power Draw Idle (Watts)	51	65
Power Draw Load (Watts)	184	198
CrystalDisk Sequential Read (MB/s)	549	532
CrystalDisk Sequential Write (MB/s)	504	501
Far Cry Primal (Avg fps)	42	42
3D Mark: Fire Strike Extreme (Index)	9,682	9,785
Maximum OC Achieved (GHz)	5.3	5.3

Best scores are in bold. Our test bed consists of an Intel Core i7-8700K, 16GB (2x 8GB) of Corsair Dominator Platinum DDR4 3200, an Nvidia GeForce GTX 1080, and a 500GB Samsung 850 Evo SSD. *Far Cry Primal* tested at Ultra at 4K.

SPECIFICATIONS

Chipset/Socket	Z370/1151
Form Factor	E-ATX
Memory Support	64GB DDR4 @ 4,133MT/s
M.2/U.2 Support	3+2 M.2, 1x U.2
SATA Support	6
Max PCIe Support	4x PCIe x16
Rear I/O	3x Gigabit Ethernet, 1x Wireless A/C, 1x PS/2 port, 7x USB 3.1 Type A, 1x USB 3.1 Type C, 5.1 audio, optical audio out, 0.25-inch headphone jack

Intel Core i5-8400

More cores. Less cash. What's not to like?

IT'S TAKEN the better part of a decade, but Intel has finally upped the core count of its mainstream PC processors. Give it up for the new Coffee Lake chips!

As we've explained elsewhere, the big news with the Coffee Lake generation is the jump from two cores and four cores to four cores and six cores. In other words, where once you got two cores, now you have four. And where you had four, you now get six. This new Core i5-8400 replaces the quad-core Core i5-7400. So, it's a six-core beast. Like previous Core i5 models, it doesn't support HyperThreading, so that's six cores and just six threads. Also somewhat similar to before is the price. Intel lists the Core i5-8400 at \$182; however, they're currently retailing for \$200, meaning 50 percent more cores for almost the same money. Nice.

What's more, you don't lose out much by way of clock speeds, either. OK, the base clock has dropped from 3GHz to 2.8GHz, but the top Turbo frequency is actually up fairly dramatically, from 3.5GHz to 4GHz. What's more, the L3 cache memory pool has grown from 6MB to 9MB. What you don't get, however, is a great deal by way of additional architectural enhancements. Intel hasn't made much noise about improvements to the CPU cores themselves, for instance. The new Coffee Lake chips are also still made with 14nm transistors, just like other Intel processors dating back to the Broadwell generation in 2014, though Intel does state

that Coffee Lake benefits from a revised production node known as "14nm+."

Similarly, the integrated graphics core is essentially carried over. It now runs at 1.05GHz peak instead of 1GHz. And it has better support for outputting at 4K. But as a gaming proposition, Intel's integrated graphics core seems to be stalling. It was never very convincing, of course, but it now looks entirely redundant. Better to remove it from the chip altogether and lower the price, or replace it with more CPU cores perhaps. After all, how many customers are going to run the likes of this new Core i5-8400 on integrated as opposed to even a low-end discrete GPU? Very few, we wager.

PLATFORM GAMES

Anyway, the final major factor to consider before we dive into performance involves platform support. If anything, this is the big disappointment with the new Coffee Lake chips. For starters, you need a new motherboard, despite Coffee Lake being pin-compatible with Sky Lake. Intel says that's because the new chips require more power. Sadly, however, the new Z370 chipset appears to be a rebadge of the old Z270, with no new features. Likewise, the new chips don't have additional PCI Express lanes in and out of the CPU die compared with their Sky Lake progenitors. Pity.

What isn't disappointing is performance. As we'd expected from the detailed specifications, the 8400 clocks up to 3.8GHz with all six cores under heavy load. So,

you're getting a really nice combination of core count and operating frequency, especially considering the modest price point. That's just as well, given this is not a "K" series model, so overclocking is not an option. But remember, these are proper, modern Intel CPU cores. In fact, they're the best cores in the business—better even than AMD's impressive new Ryzen cores. From a multithreading perspective, it absolutely blows away previous Core i5 models, and it's close enough in terms of single-threaded performance that you'd never feel the difference.

Of course, where the old Core i5 really scored was as a gaming CPU. Arguably, there are relatively few current games that really scale well beyond four cores. However, as more and more games appear that make the most of the multithreading capabilities of the new DX12 and Vulkan APIs, that could well change. With this fantastic six-core Core i5, you're ready to cash in if and when that happens. In the meantime, you've got a great all-around CPU at a surprisingly affordable price. We like. We like a lot. —JEREMY LAIRD



Intel Core i5-8400

SIX OF THE BEST More of Intel's finest cores for less cash; decent clocks; superb all-around performance.

BIT OF A HEX Needs a new motherboard; doesn't support overclocking; no new platform features.

\$200, www.intel.com

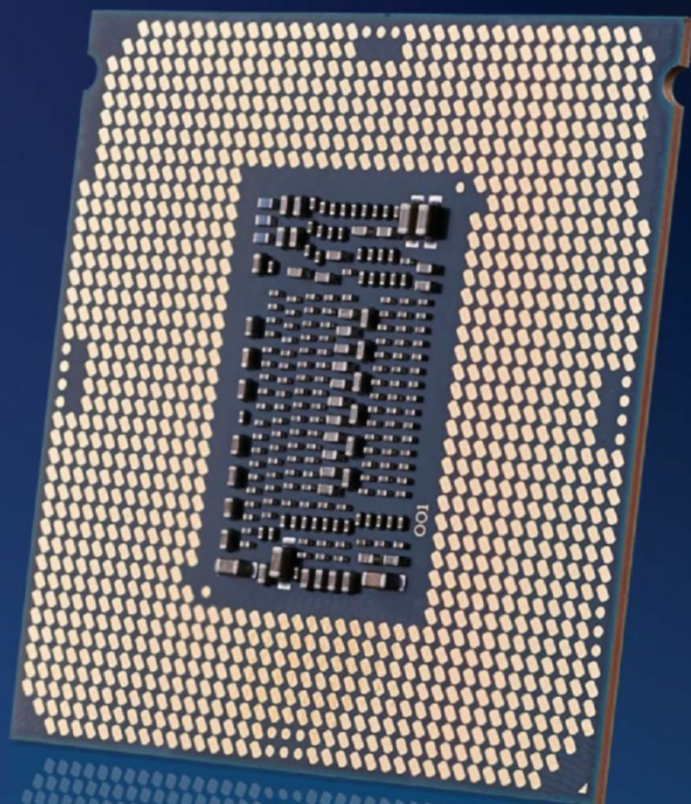
BENCHMARKS

	Intel Core i5-8400	Ryzen 5 1600X	Intel Core i5-7600K
X265 Benchmark (fps)	22.2	22.18	15.86
Cinebench R15 Single (Index)	165	159	179
Cinebench R15 Multi (Index)	949	1,223	663
Fry Render (Seconds)	230	226	346
AIDA64 Memory Latency (ns)	69	104	58
Total War: Attila (fps)	41	36	40
Far Cry Primal (fps)	77	74	77
3DMark: Fire Strike (Index)	15,405	14,875	15,762
Power Draw Idle (Watts)	47	45	44
Power Draw Load (Watts)	112	115	103

Best scores are in bold. Our test bed consists of an Asus Z370 Maximus X Hero, 16GB (2x 8GB) of Corsair Dominator Platinum DDR4, an Nvidia GeForce GTX 1080, and a Samsung 850 Evo 500GB SSD. All games were tested at 1440p on the highest graphical profile.

SPECIFICATIONS

Base Clock	2.8GHz
Turbo Clock	4GHz
Cores/Threads	6/6
Lithography	14nm+
Cache	L3 9MB
Memory Support	64GB DDR4
Memory Channels	2
Max PCIe Lanes	16
Graphics	Intel UHD 630
Graphics Clock	1.05GHz
TDP	65W



Intel's mainstream Core i5 chips now pack six beefy CPU cores.

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ADATA XPG Gammix S10 512GB

Looks like a sports car, goes like a sedan



YOU CAN GIVE A CAR fancy European styling, but what's the point if it's plain old Detroit iron underneath, and a pushrod motor under the hood? That's the kind of conundrum posed by ADATA's newest SSD. Well, kinda. ADATA has dressed up its latest PCI Express SSD in enthusiast-friendly threads. It's given it "gamer" branding, yet this is not a high-end drive. It's an entry-level SSD in the M.2 category. We give you the new ADATA XPG Gammix S10, test-driven here in 512GB spec.

For the record, the Gammix has the same components and specs as ADATA's own bare-bones drive, the SX7000. Only the snazzy heat spreader separates the two. Either way, you get 512GB of Micron 32-layer 3D TLC NAND memory arranged in 384Gb chips, marshaled by a Silicon Motion SM2260 controller, and hooked up to the system via four PCI Express 3.0 links. Sustained throughput is rated at 1,750MB/s for reads and 850MB/s for writes, while IOPS are 140K and 130K.

Of course, not all of us speak fluent SSD. So let's put those numbers into context. Arguably, the gold standard in the M.2 segment is Samsung's 960 Pro. On paper, the 512GB variant gives this ADATA drive a pretty comprehensive hammering. Sequential throughput clocks in at 3,500MB/s and 2,100MB/s, while Samsung claims up to 330K IOPS for reads and writes. In other words, the 960 Pro isn't just a bit quicker by the claimed numbers,

it's whole multiples faster. What's more, ADATA itself offers faster M.2 options.

On the other hand, ADATA matches Samsung's five-year warranty. It's also a bit cheaper than the 960 Pro. But this is where the Gammix's problems begin. On current pricing, it's only \$10 cheaper. Worse, the very similar ADATA SX7000 512GB can be had for just \$188. That's over \$90 cheaper. To put it another way, it's \$90 for the heat spreader. The SX7000 even has the same five-year cover as the Gammix.

DATA DELIVERY

That all reflects the vagaries of product cycles. As a new entrant, the Gammix's price has yet to find its comfort zone. In the meantime, it's hard to make an argument for this drive as an on-paper proposition. It's equally hard when you factor in its actual performance. In terms of sequential throughput, it delivers on the theoretical spec in some tests. Meanwhile, 4K random access performance is tolerable for this class of drive, rather than spectacular.

As a frame of reference, even in mere 250GB spec, Samsung's mainstream 960 Evo M.2 drive beats the Gammix in every synthetic metric, bar 4K random writes. Perhaps even more of an issue is the real-world feel of the drive. When it comes to sustained data writing, it's one of those drives that seemingly cycle up and down in performance. It gives the impression of a controller chipset inefficiently using the

RAM cache as a write buffer, enabling the drive to momentarily achieve high speeds before the RAM is filled and then transfers its data to the NAND cells. As for how much impact the heat spreader has, it's hard to be sure. But if we had to put money on it, our bet would be pretty much none. Whatever way you look at it, the Gammix doesn't have terribly consistent real-world performance when writing large data sets.

The flip side is subjective performance that's still very zippy. It's a lot quicker than a SATA SSD by most measures. For day-to-day computing, you're never going to feel the difference between the Gammix and even the fastest alternative drives. So, all ADATA really needs to do is tweak the price to match the performance, rather than the Gammix's misleading enthusiast aesthetics. Until then, there are better options at this price point from the likes of Samsung, or equally good alternatives for far less from ADATA itself. —JEREMY LAIRD

VERDICT
6 **ADATA XPG Gammix S10 512GB**
❑ **FERRARI LAFERRARI** Snazzy styling; quicker than a SATA drive; tolerable specs.

❑ **OLD FORD FAIRMONT** Unimpressive for M.2 drive; too expensive versus the competition. \$280, www.xpg.com

BENCHMARKS

	ADATA XPG Gammix S10 512GB	Samsung 960 Evo 250GB
30GB Internal Copy (Seconds)	230	89
Atto Sequential Read (MB/s)	1,780	3,019
Atto Sequential Write (MB/s)	886	1,494
CrystalDiskMark Sequential Read (MB/s)	1,175	1,682
CrystalDiskMark Sequential Write (MB/s)	866	1,475
CrystalDiskMark 4K Read (MB/s)	38	64
CrystalDiskMark 4K Write (MB/s)	213	191

Best scores are in bold. Our test bench consists of an Intel Core i7-7700K, an Asus Maximus IX Hero, an Nvidia GeForce GTX 1080, 16GB of Corsair Dominator Platinum DDR4, and a Samsung 960 Pro OS SSD.

SPECIFICATIONS

Capacity	512GB
Interface	PCI Express 3.0 x4
Control Protocol	NVMe 1.2
Controller	Silicon Motion SM2260
NAND Type	32-layer 3D TLC
Sequential Read and Write	1,750MB/s and 850MB/s
Read/Write IOPS	130K/140K
Warranty	Five years



MSI's first mainstream triple-fan card is no slouch.

MSI GeForce GTX 1080 Ti Gaming X Trio

AIB versus Founders versus Titan Xp

WHEN CHOOSING which GPUs to review, there's a simple process of elimination we go through. Typically, we review a reference card on launch, then, if it's interesting enough, one aftermarket variant, and generally that's it. To cover more than that, it has to be exceptional in one way or another. MSI's Trio is one such card.

Admittedly, this isn't the first tri-cooler we've seen from MSI, although that three-fan design has usually been reserved for the two-and-a-half-slot, high-end, Lightning overlocking variants, which aren't readily available, and often come at such a high price point it's enough to make even the mighty Titan Xp sweat.

So, what's so interesting? Think of this as MSI's equivalent to Asus's DCIII. Or a Tri Frozr cooling solution, instead of its usual Twin Frozr. Now, let's be clear, the Twin Frozr is still a solid and dependable cooling choice, capable of keeping even the GTX 1080 below 70 C under load in some of the most airflow-restricted cases out there—so why the big push for the triple fan? Well, the general public is under the impression that the more fans you have, the cooler you can keep it, and although that is somewhat true, nothing in our eyes trumps good heatsink design, something at which MSI has always excelled.

That aside, the Gaming X variants are now looking to be available to the

mainstream at a far more affordable price, and coupled with the GTX 1080 Ti GPU at its core, this is a prime outing for the new cooler. Packed with a fully custom PCB, designed from the ground up for improved power delivery, and the inclusion of RGB lighting, it's easy to see why MSI chose the GTX 1080 Ti as its base for the Trio's first outing. We'd be surprised if the next generation of cards didn't come with Trios as standard, across everything from the GTX 2060 upward.

So, how good is it? And how much of a difference does that custom PCB make? Well, it all comes down to memory and GPU core clock speeds. In brief, with the help of GPU Boost, the MSI Gaming X Trio's stock performance was exceptional in our testing, and far closer to the Titan Xps we featured in our Dream Machine 2017 build than we'd like to admit.

At 1440p, we saw average frame rates as high as 106 in *Far Cry Primal*, 63 in *Rise of the Tomb Raider*, and 57 in *Total War: Attila*. In comparison, the Titan Xp at stock scores average frame rates of 107 in *Primal*, 64 in *Rise*, and 58 in *Total War: Attila*—that's a one-frame-per-second difference, for a card that costs \$400 more.

It's cool, too. Seriously so. While overlocking and running stress tests, we achieved a maximum temperature of 58 C. Impressive enough, even at stock, but we

weren't anywhere near that, pumping an extra 120MHz into the core and 270MHz into the already overclocked memory.

MSI has really hit it out of the park with this one. The Gaming X Trio is an impressive redesign of an already impressive card, with incredible stock performance and cooling. It's a heavy beast for sure, even coming with its own reinforcing bracket in the box, but the trade-offs are few and, to be frank, it's one of the best GTX 1080 Tis we've seen. The big questions lie with the following: Can you stomach the \$80 price hike for the additional performance, on top of MSI's own and currently most affordable GTX 1080 Ti ARMOR edition? And do you mind the slightly off-putting RGB LED lighting design? If the answers are yes and no respectively, the Trio is likely the best GTX 1080 Ti for you. —ZAK STOREY



MSI GeForce GTX 1080 Ti Gaming X Trio

TRIFORCE Exceptional 1080 Ti performance; quiet; cool; impressive design.

TRIBE Big; slightly more power draw; \$80 more than stock.

\$800, www.msi.com

BENCHMARKS

	MSI GeForce GTX 1080 Ti Gaming X Trio	Nvidia GeForce GTX 1080 Ti FE
Total War: Attila (fps)	38/57	36/55
Far Cry Primal (fps)	90/106	86/101
The Division (fps)	67/104	44/95
Rise of the Tomb Raider (fps)	18/63	23/57
3DMark: Fire Strike Extreme (Index)	12,937	12,037
3DMark: Time Spy DX12 (Index)	9,017	8,307
Power Draw Idle (Watts)	63	47
Power Draw Load (Watts)	378	354

Best scores are in bold. Our test bed consists of an Intel Core i7-7700K, 16GB of Corsair DDR4 @ 2400, an Asus Maximus IX Hero, and a 500GB Samsung 850 Evo SSD. All games are tested at their highest graphical profile, with AA turned up, at 1440p.

SPECIFICATIONS

GPU	Pascal
Lithography	16nm FinFET
Transistor Count	12 billion
CUDA Cores	3,584
Texture Units	224
ROPs	88
Core/Boost Clock	1,569/1,683MHz
Memory Capacity & Type	11GB GDDR5X
Memory Speed	11,124MHz
Memory Bus	352-bit
TDP	250W
Display Connectors	DVI-D, DisplayPort 1.4, HDMI 2.0(A)

Eurocom Q5

Hot-blooded high performer

EUROCOM IS KNOWN for its customizable portable workstations, but every system we've tested so far has been, well, let's just say bulky, and leave it at that. Things are different this time, as we've got Eurocom's Q5 in for testing—another svelte laptop built on the foundation of Nvidia's Max-Q philosophy. Spec for spec, the Q5 is very similar to MSI's GS63VR Stealth Pro that we tested last month, so our big question this time around is how much bearing does different manufacturers' interpretation of the Max-Q philosophy have on performance, power, and design. In other words, who did it better?

That's a tough question to answer. The Q5 starts at a lower price point—only \$1,599 for a stripped-down system of Core i7-7700HQ, 8GB RAM, GTX 1070 Max-Q—but quickly balloons in price once you start going for complete parity with the GS63VR. So, let's talk about the configuration we tested: \$2,499 for a beefed-up spec that includes a super-fast Samsung 960 Pro SSD, 16GB DDR4-2666, and a 120Hz screen.

The 960 Pro is an outstanding inclusion, but also the priciest. Its blistering-fast CrystalDiskMark results (not to mention near-non-existent game load times) really show the difference between Samsung's performance M.2 line and the slower (but still excellent) 850 Evo. Having said that, it's

hard to justify dropping several hundred dollars for something like load times, when the cost could be put toward in-game performance. Of course, Eurocom's systems are customizable, so it's easy to pick the storage spec that fits your needs.

This brings us to the screen, one of our larger disappointments. The Q5's base spec features a fairly standard 60Hz IPS panel, but our unit featured a 120Hz panel, putting it in line with the GS63VR. While neither featured G-Sync support—an unfortunate exclusion—the Q5's 120Hz option is of the TN variety. Colors appear washed out, despite professional calibration. There's also a 4K IPS option, but again, only 60Hz, and the Max-Q GTX 1070 GPU would have a tough time performing at that resolution.

Speaking of the GPU, let's talk benchmarks. In our gaming tests, the Q5 performed more or less in line with the GS63VR: 56fps in *Total War: Warhammer II*, and 43fps in *Ghost Recon: Wildlands*—almost identical to the GS63VR's scores. In *Rise of the Tomb Raider*, however, the Q5 took the lead by nearly 20fps—89 to the GS63VR's 71. 3DMark Fire Strike similarly returned a slightly higher score: 11,957 for the Q5 versus 11,338 on the GS63VR.

Unfortunately, these higher scores were not without drawbacks. Namely: heat. Temperature control was always the biggest

question mark of the Max-Q design, and it seems that Eurocom's efforts on that front don't do much to assuage our worry. The Q5 got extremely hot during benchmarking and regular gameplay: We measured 43 C in the WASD area of the keyboard, 49 C on the keyboard near the center, where the CPU and GPU are located, around 54 C on the metal above the keyboard, and as hot as 62 C on the underside, where the processors are located. For comparison, the GS63VR measured 54 C at its hottest, and that was the air being spat out of the vents. Temperatures on the chassis itself remained much cooler.

So, who's the winner? Hard to say. For customizability and top-end performance, the Q5 gives you a lot more to work with, but you have to deal with the price tag that comes along with it. The GS63VR Stealth Pro offers a complete package that's hard to say no to. Either way, both systems beat the hell out of a Mac. —BO MOORE

VERDICT

8

Eurocom Q5

■ **QUICKSILVER** Light and thin; super-fast storage; highly customizable.

■ **QUICKSAND** TN screen; extremely hot.

\$2,499, www.eurocom.com

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Single (Index)	155	161 [4%]
CrystalDisk QD32 Read (MB/s)	554	1,969 [255%]
CrystalDisk QD32 Write (MB/s)	516	1,778 [245%]
PCMark 10 Express (Index)	4,084	4,519 [11%]
3DMark: Fire Strike (Index)	11,338	11,957 [5%]
Rise of the Tomb Raider (fps)	71	89 [25%]
Total War: Warhammer II (fps)	55	56 [2%]
Tom Clancy's Ghost Recon: Wildlands (Avg fps)	43	43 [0%]

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our laptop zero-point is the MSI GS63VR Stealth Pro-078, with an Intel Core i7-7700HQ, 8GB GTX 1070 Max-Q, and 16GB of DDR4. All game tests are performed at 1080p, at the highest graphical profile.

SPECIFICATIONS

Processor	Intel Core i7-7700HQ @ 2.8GHz
Graphics	GeForce GTX 1070 Max-Q
RAM	16GB DDR4-2666
Screen	15.6-inch 1080p 120Hz Matte TN
Primary Storage	512GB Samsung 960 Pro M.2 SSD
Cooling Solution	Copper CPU and GPU heatsink
Battery	Four-cell 60Whr
PSU	180W
Total Weight	4.2lb



Eurocom's Max-Q entry offers customizability, but it sure runs hot.

Kingston HyperX Cloud Alpha

One iteration closer to Cloud Nine for Kingston

FOR AS LONG as humankind has been able to pass an electrical current through a circuit board, we've been singing the praises of Kingston's HyperX Cloud headset in its various forms. It began with QPad's QH-90 in 2013, taking its cues from aviation headset design, and setting a new high bar for closed-cup gaming sound. Kingston bought the rights to that design and iterated on it with the Cloud and Cloud II, which didn't reinvent the wheel but did find sonic improvements, and introduced new features. What can the Cloud Alpha do to make good on its prestigious name, then?

Even better sound. Duh. What's more interesting than that non-revelation is how the Alpha does it: using separate chambers within each earcup for bass, mid, and high frequencies, giving each the room to resonate individually without distorting. In truth, many high-end gaming headsets, and headphones aimed outside the gaming space, adopt this principle, but the execution of it here yields audible benefits.

The frequency response on offer here is absurd: 13Hz–27kHz, one of the widest we've ever tested in a gaming product. While you won't be able to magically hear below 20Hz, no matter how diligently you've worn foam earplugs at death metal shows, the increased headroom (and, um, cellar space?) above and below the audible 20Hz–20kHz range does matter. In that extra space are subharmonic frequencies that enrich the audible frequencies. In hi-fi salesman terms, that equates to extra "low-end power" and "sparkle."

Elsewhere, it's a case of the fundamentals done right. Comfort has long been a strength of the Cloud series—as you might guess from its name—and the Alpha is just as much of a pleasure to wear, despite gaining an extra ounce in weight over the Cloud II, probably due to the new chamber design. Comfort levels are noticeably improved over the Cloud II, but it's nice to see an already high standard

maintained in this new model, particularly as it sticks at the \$100 price point.

We're glad to see that the cable is now detachable. After years of service, our Cloud II passed over to that great recycling plant in the sky when its cable died. But with this model, a broken cable connection wouldn't mean the death of the whole headset. It's business as usual for the mic: detachable, covered in a generous memory foam pop guard, and offering decent noise-canceling. Apparently, this was a focus for Kingston when designing the Alpha, to the extent that it tuned the mic specifically to cancel the frequencies that Cherry MX mechanical switches produce, but to our ears, the result is about the same—still short of Sennheiser's amazing quality, but better than most. The inline control sees a redesign, but we're less impressed by its underwhelming plastic construction than the rest of the package. The double-sided volume scroll wheel is handy, but the mic mute switch is a bit sticky, and without a clip to keep it close by, it can get lost when your eyes are locked screen-ward.

If you're still using a pair of Cloud IIs, you have no reason to panic about the advent of a new model. The improvements are small; significant enough that those without a decent headset have a more persuasive argument from Kingston than

ever to invest, but not enough that the Cloud II is now obsolete. This isn't an alpha that tries to neg you, or grunts obnoxiously after every deadlift at the gym, but nonetheless, it does exert its dominance at the \$100 price point, and should thus be considered the go-to headset for anyone in need of an upgrade. —PHIL IWANIUK

VERDICT
9

Kingston HyperX Cloud Alpha

■ **CLOUD NINE** Still well priced; still comfortable.

■ **CLOUD STRIFE** Flimsy inline control.

\$100, <http://hyperxgaming.com>

SPECIFICATIONS

Driver Type	50mm
Impedance	65 Ohms
Design	Closed-back circumaural
Microphone Type	Noise-canceling electret condenser
Frequency Response	13Hz–27kHz
Connection Type	3.5mm
Cable Length	1.3m + 2m
Weight	10.5oz



Logitech Brio 4K Stream Edition

Too much webcam, or just enough?

YOU'RE A LOGICAL READER. You've seen the headline up there, you're asking one-word questions such as "what" and "why," and frankly you are completely justified. On the face of it, Logitech has gone absolutely mad with power. The company's engineers (who have, it must be said, been on fire recently) realized that they could create a 4K webcam without stopping to think if they should. Then its marketers slapped the word "stream" on it, despite the fact that rendering and uploading a stable 4K stream is beyond most PCs, Internet connections, and streaming hosts. And then its power-crazed number-crunchers decided \$199 was a perfectly reasonable price for such a thing. All this, when Logitech already has a 1080p webcam on its roster in the shape of the C922.

But looking back a year, we were critical of the Brio's predecessor when it hit our reviews desk. Its somewhat noisy sensor, topping out at 30fps at full res, wasn't good enough to justify its \$100 price tag. It clearly lagged behind the much stronger sensors included with phones. "It's time," we said, "for the tech to take the next step." So reproaching Logitech for going all out, when it has produced precisely the webcam we asked for, would be incredibly hypocritical of us. This really is that dream device: a higher resolution sensor, HDR support, wider angles, up to 90fps capture, and support for Windows Hello on board. Even the stand has been improved, including additional points of articulation, and a standard camera-mount thread, so the Brio can be attached to a tripod.

The fact that the Brio's sensor can pull a respectable 4K image at 30fps shouldn't be its major sell, though. It can certainly do that, although the results at full stretch are rather noisy and grainy. This is definitely still a webcam, as opposed to a broadcast-ready 4K camera. It's when you drop it down to more realistic resolutions that the

power behind the sensor really shows; at 1080p 60fps, it's crisp and smooth, and at 720p 90fps—still a perfectly acceptable streaming resolution, we'd argue, and buttery with it—the results are remarkable. HDR support really does make a massive difference to the color depth, with scenes and lighting conditions that previously felt pallid and clammy rendering much truer.

The breadth of the sensor has a bunch of uses beyond its full resolution, too. Below 4K, you can adjust the viewing angle between your choice of 65, 78, or a mighty 90 degrees for those with particularly wide faces, or use the much-improved driver within the Logitech Gaming Software app to virtually pan and tilt its viewport, framing you perfectly, even if it's not pointing directly at your face. You're also given a high level of control over brightness, saturation, white balance, and more. Background replacement is still a thing and, thanks to the Hello-compatible infrared sensor, it's much improved from the shoddy third-party implementation included with the C922. We still wouldn't use it, as it's pretty obvious, and it slips up on occasion, but it's a solid stopgap if you're unable to use a chroma key backdrop.

Excellent webcam, then. Completely overspecced, which is a true positive. And so we forgive the lunatics in Logitech's labs for their outrageous levels of ambition, and we'll even give them a pass for the word "stream." The results, at online broadcast resolution, are brilliant. It's the finance

department we take issue with at the end of the day. The Brio is, at this point, far too expensive, even considering the 12-month XSplit license that's thrown in with it. Unless you're a daily camera user whose audience—be it streaming, conferencing, or calling—will appreciate seeing every pore on your face in exquisite detail, \$199 is a massive outlay, particularly considering that you'll never really drive it as hard as it can go. —ALEX COX

VERDICT
8

Logitech Brio 4K Stream Edition
RESOLUTION Fantastic picture from 1080p down; plenty of tweakables; Hello compatibility.
REVULSION Painful price tag; patchy background replacement; 4K is generally too much.
\$199, www.logitech.com

SPECIFICATIONS

Recording Resolution	4K (30fps), 1080p (60fps), 720p (90fps)
Connection	USB 3.0 (4K or less), USB 2.0 (1080p or less)
Cable Length	7.2 feet
Compatible Software	XSplit (license included), OBS, Gameshow, Skype, Hangouts, and so on
Warranty	Two years



Phanteks Eclipse P300

The budget gods are pleased

THERE'S AN EXPECTATION when shopping for a case on a budget that you're going to end up with a bum deal. If you're looking around the \$60 mark, the likelihood of finding one with anything resembling modern-day features is slim. Cable management and modern design come at a premium. Want a PSU cover, extensive radiator support, fan mounts, cable management, and tempered glass for less than \$90? Get outta here!

The notion has always been that, cases being the least important part of any budget build, you should forsake the fancy features, and just get whatever's available with the funds you have left after buying everything else. After all, cases are all pretty much the same at this price point.

That's why Phanteks's Eclipse P300 is one of the most exciting cases we've looked at this year. A \$60 chassis, with a feature list longer than Kim Jong Un's dinner menu.

One glance at its design, and you can easily spot the PSU cover and the tempered glass side panel. But it's only once you begin building in it that the true depth of Phanteks's innovation begins to shine through. With 280mm AIO support in the front, including space-saving dust filters, located top and bottom, the forward-facing panel provides two front-installed 3.25-inch caddies for all your typical hard drive needs. Remove the rear side panel, and you'll find a single Phanteks 2.5-inch caddy for SSDs mounted to the back of the motherboard tray, and oodles of cable management room, as well. There's a metal cable cover, too, not entirely dissimilar from the one in NZXT's S310 case, yet coupled with Phanteks's championed Velcro straps, of course.

And then there's the lighting. Fully compatible with any of your aftermarket RGB syncing technology from the likes of Asus, MSI, Gigabyte, et al, you do need to invest in the cable to integrate it.

Combine all that with support for up to E-ATX motherboards as big as 275mm in width, and it's hard to pick fault with this

case. So, where are the drawbacks? Well, there's a few. Firstly, the material used—it's a basic steel chassis at heart, making it somewhat flexible, and the paint job seems to attract greasy fingermarks. On top of that, there are no rubber grommets included, no GPU power cut-out in the PSU cover, and only a single 120mm fan installed at the rear of the chassis. Our biggest gripe, however, lies with the HDD caddies. Admittedly, we did decide to stick a 2TB WD Black drive in there, but the mounting holes in the toolless design simply didn't support our drive, and we had to physically remove them from the caddy, then mount the hard drive with screws before installing it.

Ultimately, the Eclipse P300 is an astonishing feat of cost-cutting ingenuity. To find a case at this price point, packing so many modern design features, with so few drawbacks, is staggering. We'd love to see some other color variations in the future, and perhaps a V2 or a Pro line for \$10 more that addresses our HDD issues and the lack of rubber grommets and GPU cut-outs. But that aside, it's perfect for anyone looking to build a brand new budget rig. It's a chassis that should sell well, and encourage other manufacturers to rethink what they include in their budget offerings. The P300 is to cases what Ryzen was to processors, and for that we can't credit Phanteks enough. —ZAK STOREY



VERDICT
9
KICK
ASS!

Phanteks Eclipse P300

■ **MOON** Extensive feature set; tempered glass; solid price point; storage support; AIO support; subtle styling.

■ **PLUTO** Hard drive caddies.

\$60, www.phanteks.com

SPECIFICATIONS

Form Factor	Mid-tower
Motherboard Support	ITX, mATX, ATX, E-ATX up to 275mm
Colors Available	Black
Window Available	Yes
3.5-Inch Support	2 (2 included)
2.5-Inch Support	2 (1 included)
Radiator Support	280mm (front), 120mm (rear)
Fan Support	2x 140mm (front), 1x 120mm (top), 1x 120mm (rear)
Dimensions	24.2 x 15.7 x 7.8 inches
Graphics Card Clearance	13.0 inches
CPU Tower Clearance	6.3 inches
Weight	13.2lb



Logitech G603

An understated wireless wonder

LOGITECH'S LIGHTSPEED is some seriously fascinating stuff. Even after checking out the groundbreaking G613 keyboard last issue, and the Powerplay mouse-charging mat before that, we have absolutely no idea how it works, and can find no technical information on it beyond the company's own marketing spiel. Buy into that, and Lightspeed is the result of repeated refinements of every component in the wireless signal chain, from antenna geometry to circuit pathways to communications protocols. And while we still suspect either a little number-fudging or suspicious time-travel chicanery, we're happy to accept Logitech's explanations. All of this in tandem results in a reported 1ms response time, and absurdly long 18-month battery life.

Not both at the same time, though. You'll only get that length of service from the G603's dual AA batteries if you switch it to low response mode, via the base-mounted switch. This drops the polling rate from the full 1ms to a still-reasonable 8ms, and as you might expect, this has a noticeable effect on the mouse's DPI. Keep it in hi-res 1ms mode, and Logitech suggests you'll get around 500 hours of gaming out of it—still very respectable, but as this lacks the rechargeable internal battery of its more expensive siblings, you'd better have cells on hand when the Logitech Gaming Software and its single indicator LED tell you time's about up. Switching those batteries is quick and easy: Pull up on the magnetic upper shell, and the whole thing comes off, revealing the Omron upper switches and battery compartment within.

It also reveals the vast amount of engineering know-how that's gone into the

G603. The levered mouse buttons, which contact the microswitches at the same time they meet the solid braced frame of the upper shell. The precisely placed neodymium magnets, matching with fine steel screws for just the right amount of attraction. The internal slot for stowing the minuscule USB receiver while on the move. For what is, on the desk, an unassuming gray mouse—with just one tiny RGB LED, that you'll rarely see lit, and nothing else in the way of bling—this is something of a secret winner.

Even the stuff that you can't see is pretty sharp. Every button, including the DPI toggle, can be configured and switched around. The resolution levels of Logitech's Hero sensor can be minutely customized between 200 and 12,000, and all the relevant settings are stored within the mouse itself, meaning it'll perform exactly as you expect, even if you're taking it to a machine without the Logitech software suite on board. It's easy enough to use the G603 with multiple machines as it is—it supports Bluetooth alongside Lightspeed, quickly switchable via a button on its underside, so if you're doubling up on your desktop, you may be able to do without the KVM.

If we were to stop gushing for a moment and be critical instead, as our stern-faced editors insist we must, there are a couple of holes we could just about pick. The G603's slightly bulbous right-hand-only curve isn't quite as comfortable for palm grip as we might have liked, for example, and its ratcheted wheel doesn't have the same smooth bump as some of its competitors. Had the side buttons been a few eighths of an inch lower, they might have been more

quickly accessible, although sitting directly above the natural grip position does mean it's difficult to accidentally activate them. And maybe, just maybe, that price is too steep for you to consider for something so plain. But don't be so vain; this is easily responsive enough for gaming, resilient enough for years of desktop use, and flexible enough for multiple machines. It's worth the price. Lightspeed connectivity is sharp enough that it has to be at the top of your list of requirements if you're considering new wireless peripherals, and the G603 is a reasonably cost-effective way in. —ALEX COX

VERDICT

9

Logitech G603 Lightspeed Wireless Gaming Mouse

■ **GAMING MOUSE** Great sensor; awesome battery life; flexible design; fast wireless response.

■ **POORHOUSE** Slightly expensive; not for every hand.

\$70, <http://gaming.logitech.com>

SPECIFICATIONS

Sensor	Logitech
Sensitivity	200-12,000 dpi
Sensor Model	Logitech Hero
Polling Rate	1,000Hz/125Hz
Programmable Buttons	6
LEDs	1x RGB indicator
Cable Length	N/A
Weight	4.79oz (with batteries)

Sending rat ogres into archers is a hugely satisfying move.



Total War: Warhammer II

Fantasy battles meet battle fantasy once more

GAMING'S GREATEST MERGER throws up another installment, but any worries about *Total War* moving to a *Call of Duty*-like release schedule are unfounded. As the second part of a trilogy that will eventually join up into one ubergame, *Warhammer II* takes everything about the first game, and subjects it to an upgrade and polish.

Selecting "Desynchronize animations" in *Rome: Total War* used to cause a graphics card to develop heatstroke, but these days the engine is well enough optimized that last-gen cards should handle the game without a problem. That's not to suggest there's a lack of incidental animations or effects, as your tiny magicians and mounted knights crackle with lightning and swish their tails in a constant flurry of movement.

On the surface, little has changed. *Total War* is still a mixture of a strategic map game—in which you capture settlements and resources, recruit heroes, build armies, and sally forth to find other armies to get in a scrap with—and a tactical one, in which you take direct control of these regiments and heroes. Winning gains you experience and sometimes equipment for your hero, especially if you manage to take out an enemy lord, while losing sees your army either destroyed or reduced

to a shadow of its former self, and your ambitions thwarted.

Beneath the surface, though, something is scuttling. The big draw is the ability to play as the Skaven, hordes of ornery technorodents, who huff warpstone like it's paint thinner, and eat their captives. They're lots of fun. There's nothing like smashing into massed elven archers with a bunch of thuggish Rat Ogres, while your plague catapults pepper them with glowing green shots from afar. Reinforcements literally pour out of holes wherever the Skaven general chooses, right next to the cannons slaughtering your infantry, for example.

ON TO A GOOD THINGY?

This fits in with the game's structure, which is a race. There is a powerful thingy on the High Elves' island, and it's up to you to control that thingy before any other faction can. All this makes a mockery of the game's diplomacy system, as no group is going to honor a non-aggression pact when you're competing for the thingy, and makes the late game one of constant harrying from the remains of other races, as you complete rituals and defend settlements.

Ah yes, those other races. There's a couple flavors of elf, including the

dangerously wicked Dark Elves, whose slave-based economy seems like a great way to get rich, and break out the fancy war units, until you realize all those slaves might not be too happy about their situation. You can rise above it all as the haughty High Elves, or as the levitating Lizardmen. If you've got the first *Total War: Warhammer*, you can use any of its races, too, and march across the *Warhammer* world's equivalent of the Americas as Dwarfs or the Empire.

Everything looks sharp, even zoomed right in, and the backdrops—all waterfalls and jungles—have had a new coat of paint. Freed from the need to provide a history lesson with every installment, *Total War* has reached new heights. And all it took was some tabletop inspiration. —IAN EVENDEN

VERDICT

8

Total War: Warhammer II

■ **COGENT** *Total War* at its best; huge fantasy battles and sieges.

■ **RODENT** Complex interface; civil unrest and wandering armies can be annoying.

■ **RECOMMENDED SPECS** 3.2GHz Core i5-4570; 8GB RAM; GeForce GTX 770 4GB or AMD R9 290X 4GB.

£60, www.totalwar.com, ESRB: T



Tutorial prompts continue appearing on screen after many hours of play.

Middle-Earth: Shadow of War

Look who's Tolkien now

THIS IS HUGE. *Shadow of War* downloads with a 4K Cinematic Pack, and weighs in at 98GB. It's like Warner Bros is going for some sort of record. Once you've waited for the game to install—it took us a whole morning—it's time to beat up some orcs.

Games aren't movies so much as theater. The addition of a human actor to the otherwise clockwork mechanics mucks things up as much as a falling lighting rig or a romantic lead forgetting his lines. Movies are the same every time you watch them, games are not—and, outside MMOGs, this is never more the case than with the *Middle-Earth* games. The first entry in the series introduced the Nemesis System, in which named enemies you don't kill the first time you meet hold grudges, carry out ambushes, and become more powerful if they do manage to kill you.

The whole look is indebted to Peter Jackson's *Lord of the Rings* trilogy, but the lead characters, human ranger Talion and elf-ghost Celebrimbor, take Tolkien to new depths of grimness. They're dark knights who fight like Batman, terrifying their prey and leaping from enemy to enemy as they flit between weapons and spectral special moves. Glossing over the sexy spider-lady, it's the verbose orcs who

are the real stars, a hilarious deep voice intoning their name as you meet them, even if they exist only to utter their lines before you run them through with your sword.

ALL OVER THE LOOT

There's a point to this orc-wardness, and it's taking control of fortresses. Each fortress is controlled by a war chief, who has several captains who boss the grunts about. We've played this game before—*Crackdown* comes to mind, as you take out captains to undermine the war chief, and gather intel on his weaknesses, before taking him on, and capturing his fortress. There are also human cities to be protected, skills to be learned, weapons to be collected, followers to be recruited, and loot boxes to be opened.

Ah, yes, the Internet got very upset about loot boxes, but they're nothing to worry about. Yes, your pal could buy legendary weapons and epic followers, and therefore have an easier time in the game, but you could spend the same amount of money on burgers, and probably have just as good a time. You earn currency from fights and old equipment, which can be spent at the market on gear and followers. If you want, you can buy gold with real dollars, which can be spent on different chests, but we never felt it was

necessary. The flow of new gear didn't feel as if it was being artificially throttled.

Throttling an orc, incidentally, drains their health, transfers it to you, then makes their head explode. So there's that. You're told about this, and the game's many, many other systems, moves, and features by a tutorial system that begins to feel like it's never going away. The save system, conversely, very much seems to have gone away—it's so transparent that it's not clear if it's saving or how long ago the last one was. The "unsaved data will be lost" warning when you quit takes on new terror when you're really not sure....

Shadow of War is a worthy sequel to *Shadow of Mordor*, taking that game and making it bigger and nastier. Becoming a superhero in Tolkien's world is fun, but the emergent stories the Nemesis System supplies are unforgettable. —IAN EVENDEN

VERDICT
8 **Middle-Earth: Shadow of War**
■ **SHADOWFAX** Many orc characters to kill or dominate; combat makes you feel powerful.

■ **SHADOWY** Dull heroes; not amazing-looking; Gollum is in it.

🔧 **RECOMMENDED SPECS** AMD FX-8350 or Intel Core i7-3770; 12GB RAM; 4GB AMD RX480, 4GB Nvidia GTX970, or 6GB GTX1060.
\$60, www.shadowofwar.com, ESRB: M



LAB NOTES

JARRED WALTON, SENIOR EDITOR



GTX 1070 Ti: Stuck in the Middle

Nvidia's taps another nail into Vega's suspiciously empty coffin

2017 HAS BEEN A GREAT YEAR for technology, with more major CPU launches in a single year than I can recall ever seeing. We've also had a lot of excitement in the GPU arena, with the GTX 1080 Ti, Titan Xp, Volta GV100 for deep learning, and AMD's RX Vega. The last was disappointing, because on paper Vega looked like it might be a contender. Instead, we got a power-hungry GPU that couldn't even claim a decisive win over Nvidia's parts that launched a full year earlier.

But competition in the graphics card market can be brutal. The 1070 trails Vega 56 by as much as 10–15 percent in individual games, and overall it's a few percent slower. Never mind the supply problems AMD continues to experience several months after the official launch, with higher than expected pricing. Never mind the distinct lack of custom Vega cards—a few

are on the way, but graphics card vendors seem to be just as unimpressed with Vega as we are, and cooling a card that can pull well north of 350W when overclocked is no mean feat. AMD winning at

any level simply won't do, says Nvidia, so here's an upgraded 1070 Ti.

Nvidia is pouring salt into the Vega wound, and it hurts. The 1070 Ti slots in nicely midway between the 1070 and 1080, in price as well as performance. But did we really need another high-end \$450 Pascal-based GPU? No, but it gives Nvidia a new



Nvidia is determined to give AMD's Vega a hard time.

product SKU for the holiday shopping spree, which is never a bad idea. More importantly, the 1070 Ti provides a solid 10–15 percent boost in performance relative to the vanilla 1070. That's enough to clearly beat Vega 56 and match Vega 64.

But what I wanted was a GTX 1060 Ti to fill the void in the \$300 space. Maybe next year.



ALAN DEXTER
Executive Editor

I can't resist a bargain, so was delighted when I spotted *Layers of Fear* for free for Twitch Prime members (a game that's been on my Steam wishlist for ages). The deal was apparently available from Oct 24–Nov 1, though I didn't spot it until Nov 2, so there may be some leeway. The interesting thing is that the game appears in the Twitch Desktop app

under the "My Games" tab, as opposed to just a Steam code. Normally, I wouldn't condone having yet another game service on my machine, but as the Twitch app was already there, this was less of an issue. Hopefully, we'll see more of these freebies going forward, though it does mean that's another app you've got to keep an eye on for deals.



BO MOORE
Technology Editor

Eagle-eyed readers will notice that we've updated our suite of system benchmarks. Gone is *Far Cry Primal* and *The Division*, replaced by *Total War: Warhammer II* and the extremely demanding *Ghost Recon: Wildlands*. The other major change was how we measure battery life. Instead of a standardized benchmark, we wanted to come up with a

test that simulated a moderate workload but was still easily repeatable. The test we settled on is simple but effective: set the laptop to the balanced power setting, 40 percent brightness, and run a Twitch stream in Chrome at full screen, measuring from the moment I unplug to when it shuts down at 5 percent. Simple, repeatable, effective.

Editors' Picks: Digital Discoveries

Tuan Nguyen, editor in chief, and Zak Storey, deputy editor, consider a cornucopia of computing conundrums



SEAGATE IRONWOLF PRO 12TB

I'm a sucker for storage, ludicrous amounts of storage. This is why I've decided that the batch

of 12 5TB hard drives in one of my NAS units isn't worthy of my decadent hardware obsession any longer. I'm going to upgrade them to Seagate's new IronWolf Pro 12TB drives—all 12 drives. That's 144TB of storage in one NAS.

Seagate's IronWolf line is designed for the demanding 24-hour operation that's required of a NAS-focused hard drive. There's no rebooting or shutting down, and up time is everything. What's more, the IronWolf Pro series is designed to go even further, which makes its five-year warranty worth the price premium. The hardware on the IronWolf Pro is also made to both last and endure punishing workloads. Seagate rates the drive at an average of 300TB of I/O per year, and the firmware on the drive is tuned for multiple simultaneous users.

In terms of raw speed, the IronWolf Pro is as fast as any 12TB spinning disk can get, with a 250MB/s transfer rate. Although this isn't as fast as a SATA SSD, it's fast when it's set up as a RAID in a 12-drive configuration, and piped through a 10-gigabit Ethernet connection. Raw random access rates aren't important, just total sustained throughput. Yes, for me, only the most ridiculous hardware will ever suffice. \$500, www.seagate.com



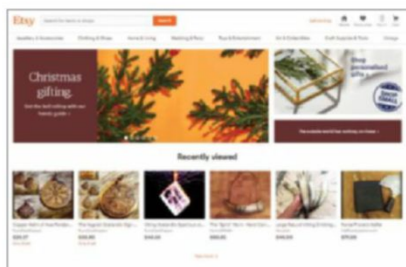
ETSY

Christmas is a-coming, and that means gifts. Now, call me old-fashioned, but I like to put a little thought into

the presents I give to the people who are closest to me. I rarely ask people for their lists, because I'm not that kinda guy. Don't get me wrong, Amazon and lists have their place, but when it comes to my old pops and ma, nothing beats something handcrafted and tailor-made.

Which is why I do a lot of my Christmas shopping at Etsy. With small-scale businesses selling handmade goods, Etsy is a marketplace not too dissimilar from Amazon, but it's the differences that make it infinitely more valuable in my eyes. Firstly, it's a global marketplace—you can buy from and ship to anywhere the seller accommodates—and, more importantly, most of the merchandise is handcrafted by folks who care about it. You'll struggle to find any of the big brands selling on Etsy, because it's designed for handmade and unique goods. For example, to celebrate old Papa Storey's 50th Christmas, I've gone ahead and invested in a custom-made Viking mead horn, with his initials engraved on the side of it. It should fit the bill nicely, I reckon. I'm kinda jealous.

Varies, www.etsy.com



Razer Wolverine Ultimate

I FIND IT HARD to get excited about controllers. The use cases are slim, but a good controller is an essential part of any gaming enthusiast's PC toolkit. After all, you can't play every game with a mouse and keyboard. Well, you can, but lots of titles simply aren't as enjoyable without a game controller. Platformers, racing sims, and fighting games all feel much better on a controller than with a precision pointer and clacky keys.

I've tried a few aftermarket ones in the past, so when Razer offered me the opportunity to try out its latest Wolverine controller, I jumped at the chance to give the big ugly mammal a run for its money.

So, it's \$160. It's challenging to justify spending that much on a controller, especially when you can pick up a cheap Xbox one for just \$26 on Newegg. Mind you, it does come with everything you'd ever need: an extensively long USB cable, three swappable thumbsticks, d-pad layouts, a cornucopia of buttons (with multiple triggers hidden away at the back), fully remappable buttons, and, of course, that old Razer favorite and drifter from the world of PC peripherals, RGB Chroma lighting.

That aside, the design is really nice. The sandblasted finish dodges greasy fingers well, and the rubber grips at the back feel premium and secure. Everything is solid, and it's a stunning piece of gear to use, ergonomically slotting into your hand sweetly enough. The one thing I do wish is that it featured lighting on all the buttons. That said, if you got the cash, it's actually a fair product for the price. **-ZS**

\$160, www.razerzone.com

LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

- > Suspicious SSDs
- > Threadripper Coverage
- > Dead on Arrival

Stingy Storage

SSD prices are stuck at a stubbornly high level, typically four to five times that of a traditional hard drive of the same capacity. Why is it taking so long for prices to come down? And when do you see prices becoming more competitive with HDDs? **—Steve Hartjes**

EXECUTIVE EDITOR ALAN DEXTER RESPONDS: SSDs have actually dropped in price significantly since they first hit our machines, sliding from around \$3 per GB in 2010 to just less than \$0.5 per GB today. We are not saying they're cheap, but they're much cheaper than they were. Unfortunately, hard drives have also dropped in price, and continue to do so—for comparison, you're looking at less than \$0.04 per GB now. Very roughly speaking, \$50 will get you a 128GB SSD or a 1TB HDD.

Will we ever get to a point where we see parity between HDD and SSD pricing? I doubt it, because you're not comparing like for like. Sure, they're both used for storing data, but they work in very different ways, and rely on completely



SSDs have dropped in price, but HDDs are still ahead.

different technologies. The price hike this year is down to a general demand for flash storage, while hard drive pricing has been stable for a long time now.

There's a key factor that I haven't mentioned so far, and that's performance. If you're only interested in raw storage, hard drives are still your best option, and they're not going to go anywhere soon. However, if you care about how quickly you access that data, the value (and price) of SSDs increases significantly. We've been banging the performance

drum for years, and if you're not convinced by the benchmarks, it's worth trying an SSD first-hand. I wouldn't consider building a machine without an SSD these days. And for serious storage, I'd still have a hard drive spinning alongside it.

Total Coverage

I'm curious why you chose to use an AIO that doesn't have 100 percent coverage? The Enermax TR240 and TR360 both cover 100 percent. Using the 240 in pull mode, I have yet to see my temps go above 60 C, and that's the temps AMD is reporting, so

depending on which offset you go by, my 1920x stays insanely cool under 100 percent load. I know they are hard to find in stock, but if you want to get the max out of the chip, you shouldn't skimp on the cooling just because AMD included a free bracket. **—Scags**

DEPUTY EDITOR ZAK STOREY RESPONDS: Threadripper is a big chip, but in reality, the die under the IHS isn't the entire size of the IHS. 100 percent coverage, in our testing at least, makes little difference with regard to overall temps. We decided to use the Kraken because, at the time of writing, there were very few full-cover coolers out there, and the Kraken was the staple AIO for all our test benches.

Also, Threadripper behaves very much like its top-end mainstream Ryzen counterpart, the 1800X. In short, it's not temperature that limits overlocks, but silicon stability. If you can get over 4.1GHz on your chip, you're exceptionally lucky.

All that aside, our Threadripper sample isn't a hot chip. We have a single Noctua tower cooler (the NH-U14S TR4) currently

submit your questions to: comments@maximumpc.com

sitting happily chilling our 4GHz (at 1.35V) overclocked 1950X, and it's only hitting 75 C max under load.

Stuttering Ryzen

I've seen *Maximum PC* mention multiple times now how Ryzen can cause stuttering in some games. As a gamer, that sounds like a nightmare scenario, and makes me want to avoid the platform like the plague. I was wondering if you might be able to give this more in-depth coverage. Some examples of games that have this problem, how much measured stutter there is, reach out to AMD for any response, and so on. While it sounds like a great CPU performer overall, the last thing any gamer wants is stuttering performance from new hardware! **—Ross Scott**

DEPUTY EDITOR ZAK STOREY RESPONDS: We have noticed some micro-stuttering in one of our major benchmarks—*Total War: Attila*. But it's not a good example of an optimized game (partly why we include it in our benchmarking suite), so don't expect it to be the case for most games. As Ryzen is still a fairly new architecture in terms of resource allocation, there were a few hiccups early on with some games that were no longer being supported, *Attila* being one of them. In all modern titles, the stuttering is non-existent, although you do lose out on a few fps at 1080p with most games, due to the competition's superior single-core performance.

I've been running a Ryzen 7 1700 at home, and have had little in the way of issues so far. The only game that does come to mind outside of *Total War: Attila* (all the other *Total War* games are fine) is the first *Dishonored*, stuttering with SLI enabled, but running fine with it disabled.

Unfortunately, this is a case by case basis, which

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A WEEK WITH THE XBOX ONE X: HOW IT COMPARES TO A LIVING ROOM PC



Microsoft's latest console makes for a much better HDR Blu-ray player than your PC. What else is there to like about it?

The Xbox One X is the closest any console's come to the power and functionality of a gaming PC. It runs on a custom version of Windows, and has components that roughly compare to a \$500 gaming PC, with enough GPU power and memory to run games at 4K, but a relatively weak CPU compared to a Core i5 or i7. We've been using the Xbox One X in the living room as an alternative to Steam's Big Picture mode, trying to get a feel for how this console compares to Microsoft's first stab at the Xbox One, which was big, ugly, and had a borderline-unusable OS. The Xbox One X is an impressively powerful and compact box, by comparison.

Read the full article at <http://bit.ly/2lNhnbx>

ultimately lies on the side of the game developers, rather than that of the chip manufacturer. And as these games inevitably get older, and we advance into newer OSes, it becomes ever more likely that older titles will stop running entirely due to software issues, more so than any particular change to hardware.

Dead on Arrival

In the June 2017 issue of *Maximum PC*, on page 92, in the last paragraph, you write that one motherboard was dead on arrival (DOA), but you do not specifically state which motherboard it was. Which motherboard was DOA? How come it was not mentioned in any of the reviews? **—Scott Finly**

DEPUTY EDITOR ZAK STOREY RESPONDS: The motherboard in question was the MSI B350M Mortar. It was never mentioned in any of the reviews because it was

never actually reviewed. Under closer inspection from MSI, the board had suffered damage to the VRMs during transit, and unfortunately we just didn't have enough time to get it into the group test or a separate review. To be fair to MSI, we do see plenty of dead gear, and having seen how hardware is handled by couriers, this doesn't surprise us in the least.

Positive Switch

After reading the console head to head, I now know true review bias. I don't know where those price figures are coming from, but the Nintendo Switch I got has an MSRP \$299, so where did \$369 come from? And the round-up is very biased already, since the Switch AFAIK isn't a media playback device. And to call the Joy-Con's grip "plastic" is ridiculous, as the same can be said of the Xbox and PS4 plastic controllers. I am

beginning to see fanboy bias from the start.

Now, if this were a proper review that rated gaming enjoyment, that would be different, but it reads as though it's a poor review just to satisfy your disdain for the Nintendo Switch and how popular it is. Your article forgets that it's currently selling better than the Xbox and PS4. Nintendo isn't there to cater to outdated thinking, but to innovate when others are afraid to take the leap in console portability or next-gen gaming innovations.

For all the nitpicks about Switch hardware, neither the Xbox nor PS4 has come up with anything to rival the Switch in terms of innovation, other than "Hey, look, it's 4K!" I say meh to that. How much enjoyment are you getting, from just a fun-to-play perspective? That's something this article omits. And there are third parties making products to make the Switch easier to take on the road as well. That's what it's all about for me: the "fun-to-play" factor.

—Robert Schneider

EXECUTIVE EDITOR ALAN DEXTER RESPONDS: The pricing was taken at the time of writing, and because of the high demand for the console, it was the best price we could find (even now, many sites are out of stock). As to your other points, Alex Cox, who wrote the piece in question, is a big fan of his Nintendo Switch, and heartily recommends it, but the point of the piece was not to simply sing the praises of any one console because of one single reason, but to give readers an overview of the consoles that are currently available. As for your accusation of bias: We are biased here on *Maximum PC*, but just toward PCs (naturally). We have no preference when it comes to this latest batch of consoles; they are just playthings, after all. ☺

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MID-RANGE



INGREDIENTS

PART		PRICE
Case	Phanteks Enthoo Evolv ITX	\$70
PSU	EVGA 450B Bronze	\$45
Mobo	ASRock AB350 Gaming-ITX/ac NEW	\$95
CPU	AMD Ryzen 3 1200 NEW	\$110
GPU	MSI GeForce GTX 1050 Ti AERO 4GB	\$163
RAM	8GB (2x 4GB) Patriot Viper Elite DDR4 2666 NEW	\$77
SSD	Team Group L5 LITE 2.5-inch 120GB NEW	\$48
HDD	1TB WD Blue 7,200rpm	\$50
OS	Ubuntu Desktop Linux 16.04 LTS 64-bit	\$16

Approximate Price: \$674

GUYS, GUYS! That's a \$3 price drop on memory. Stop the press! OK, joking aside, we're finally getting confirmation that DRAM production is being upped at the start of next year, with Samsung committing one of its production facilities and an additional floor elsewhere to manufacturing memory. On top of that, SK Hynix and Toshiba are also upping their production lines at the end of 2018, so perhaps, at last, we'll see those prices drop. Anyhow, that aside, we've finally jumped the gun, and swapped across to Ryzen 3 for our budget build. The Ryzen 3 1200 is a perfect little quad-core, ready for any gaming or general-use task you can throw at it. Couple it with some good memory, a decent GPU, and ASRock's AB350, and you'll have the perfect base rig for anything you set your mind to. Rendering? Upgrade to a Ryzen 7 1700 and 16GB of DDR4. Gaming more your jam? Throw in a GTX 1070 Ti instead.

INGREDIENTS

PART		PRICE
Case	NZXT S340 Elite	\$95
PSU	EVGA SuperNOVA 550 G2	\$90
Mobo	MSI X370 SLI PLUS	\$140
CPU	AMD Ryzen 5 1600	\$215
Cooler	Corsair H100i v2 + bracket	\$115
GPU	Zotac GeForce GTX 1070 Mini 8GB	\$400
RAM	16GB (2x 8GB) G.Skill Ripjaws V Series DDR4 3200 NEW	\$167
SSD	256GB Samsung PM961 M.2 PCIe NVMe	\$135
HDD	Western Digital Blue Series 1TB 7,200rpm	\$50
OS	Windows 10 Home 64-bit OEM	\$100

Approximate Price: \$1,507

THERE'S NOT A HUGE AMOUNT of change this month for our mid-range build. Last issue, we touched on the notion of swapping out to an Intel Core i5-8400 solution; however, due to high demand and the lack of availability reported from Intel, we simply can't recommend a system that may not be in stock until February at the earliest, so Ryzen it is. Don't get us wrong, Intel's latest Core i5-8400 series chip is a stomper, but if it's not available, it's not available. That said, the Ryzen 5 1600 is hardly a wet fish, and still a good solution at this price point. We did have to change the memory out to a lower specced G.Skill Ripjaws solution, instead of the classier Trident Z, but that aside, there's little else to complain about here. The GTX 1070 is also still a solid solution for 1080 and 1440p gaming, and we haven't been hands-on enough with the GTX 1070 Ti just yet to suggest swapping out to that overclocking king.



SO, WE'VE DROPPED DOWN to a slightly lower spec memory kit this issue, and it's still costing us \$10 more than last month. On the plus side, it's RGB.... So, that's a thing. Apart from that, we haven't changed a great deal. The 1920X is a fantastic 12-core part, capable of delivering some incredible rendering performance. Combine that with 32GB of high-spec DDR4 and the GTX 1080 Ti, and you have yourself a machine that can be put to any task without fear. A batch of Noctua air coolers have recently arrived in the office, which are perfect for Threadripper, but unfortunately not yet available on Newegg. So, for the time being, we're sticking with the Kraken X62, as its block is more than enough to cool all four of those Ryzen dies, and ramp up the overclock to 4GHz, ensuring you can game just as well as you can render. Don't believe us? We currently have the 1950X running off a single Noctua air cooler, with two fans, clocked at 4GHz, registering 75 C under load.

As far as storage goes, it may well be that in the future we jump up to one of Intel's latest Optane-powered SSDs, but until they're on the market, and we've had more time to test just how well they perform in real-world benchmarks, we'll stick with what we've got.

The one place we would like to make a change is that chassis. The Eclipse P400S is a well-equipped ATX-supporting beast, but swapping out to a newer NZXT H700i would spruce up this build, and add some smart features through AI-controlled fan curves and more, which would be perfect for this kind of system.

For more of our component recommendations, visit www.maximumpc.com/best-of-the-best

INGREDIENTS

PART		PRICE
Case	Phanteks Eclipse P400S Tempered Glass Silent Edition	\$90
PSU	Corsair RM750X Modular Gold	\$100
Mobo	Asus Prime X399-A	\$350
CPU	AMD Ryzen Threadripper 1920X	\$780
Cooler	NZXT Kraken X62 280mm AIO	\$156
GPU	MSI GeForce GTX 1080 Ti ARMOR 11G OC NEW	\$720
RAM	32GB (4x 8GB) G.Skill TridentZ RGB DDR4 3000 NEW	\$360
SSD	512GB Samsung 960 Pro M.2 NVMe	\$290
HDD	4TB WD Black 7,200rpm	\$185
OS	Windows 10 Home 64-bit OEM	\$100

Approximate Price: \$3,131

UPGRADE OF THE MONTH



AMD RYZEN 3 1200

It felt odd for us to keep recommending the **trusty** Pentium G4560, so this issue we decided to swap it out in favor of a budget offering from AMD. The Ryzen 3 1200 stomps the field when it comes to multithreaded applications, and its single-threaded performance isn't bad either for the money. On top of that, if you've got a suitable cooling solution behind it, you can throw some extra volts into that bad boy, and get even more performance out of it for free, unlike the Pentium. If you're looking for the perfect budget-busting processor to start out a new build or upgrade an aging one, the Ryzen 3 1200 fits right in, like Bill Murray fits into comedy. **\$110, www.amd.com**

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